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Agriculture and livestock impacts on river floodplain wetlands: a study case from the lower Uruguay river

MARÍA JULIA BENA[1], HORACIO SIROLLI[2,3] and FABIO KALESNIK[3]

Summary: Even though wetlands are very valuable environments, they suffer heavy exploitation and transformation processes that affect their biodiversity. The main goal of this study was to characterize the herbaceous plant communities associated with the southern Uruguay River flood plain. We focused on lowlands of two farms, one of which is surrounded by an embankment to prevent flooding. A random stratified sampling was performed in 72 plots. To detect distribution patterns and plant species associations we performed a Detrended Correspondence Analysis (DCA) and a Two-Way indicator species analysis (TWINSPAN). We could identify six groups of plots whose ordination patterns are related to the flooding preferences of dominant species. Herbaceous plant groups that develop in anthropically modified environments showed the highest overall richness and diversity with the ingression of invasive species but, they formed a homogeneous patch at a landscape scale. Plant associations with minor anthropic modifications showed lower richness and diversity values but, from a floristic point of view, they formed a heterogeneous mosaic.

Key words: Uruguay river, dyking, grazing, herbaceous communities, floodable lowlands.

Resumen: Impacto de las actividades agropecuarias sobre humedales de planicies inundables: el caso del río Uruguay. A pesar de ser ambientes valiosos, los humedales sufren procesos de explotación y transformación intensivos que afectan su biodiversidad. El objetivo principal de este trabajo fue caracterizar las comunidades herbáceas asociadas a la porción sur de la planicie de inundación del río Uruguay. Para ello, nos concentramos en las zonas bajas de dos establecimientos agropecuarios, uno de los cuales se encuentra rodeado por un endicamiento que evita las inundaciones. Se llevó a cabo un muestreo estratificado al azar en 72 parcelas. Para detectar patrones de ordenamiento y asociaciones de especies, realizamos un análisis de correspondencia destendenciado (DCA) y un análisis de especies indicadoras de doble via (TWINSPAN). Pudimos identificar seis asociaciones de especies cuyos patrones de ordenamiento están relacionados con las preferencias de inundación de las especies dominantes. Los grupos de plantas herbáceas que se desarrollan en ambientes antrópicamente modificados presentan una mayor riqueza y diversidad con el ingreso de especies exóticas, aunque formando un parche homogéneno a escala de paisaje. Mientras que, las asociaciones de plantas con escasas modificaciones muestran valores de riqueza y diversidad menores, pero desde el punto de vista florístico, forman un mosaico heterogéneo de ambientes.

Palabras clave: Río Uruguay, endicamiento, pastoreo, comunidades herbáceas, bajos inundables.

[1]Instituto de Botánica Darwinion, Labardén 200, Casilla de Correo 22, B1642HYD, San Isidro, Buenos Aires, Argentina. mjuliabena@gmail.com
[2]Reserva Ecológica Costanera Sur, Gobierno de la Ciudad de Buenos Aires, Buenos Aires, Argentina
[3]Instituto de Ecología, Genética y Evolución, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Pabellón II, 4to piso, Ciudad Universitaria, C1428EHA, Buenos Aires, Argentina

Introduction

Wetland ecosystems are considered very valuable environments, not only because of the biodiversity they harbor, but also because of their economic importance. However, a large portion of wetlands has suffered and continues to suffer heavy exploitation and transformation processes. Several human activities, such as the use os dikes and embankments, artificial drainage, deforestation and livestock grazing, affect the biodiversity of these ecosystems (Junk *et al*. 2013, Wang *et al*. 2011). Many riparian species have specific requirements of hydrology; therefore, changes in water flow magnitude, duration, timing, frequency, and predictability may alter the plant community composition (Neiff *et al.* 2011). Also, modified environmental conditions, either through climate changes, eutrophication, and/or river regulation, might facilitate the spread of invasive species (Catford *et al.* 2011).

Over the last few decades, the advance of the agricultural frontier has had serious consequences for these ecosystems. Among them is cattle displacement towards wetlands, since they have traditionally been considered marginal areas for culture. Livestock farming has replaced an extensive seasonal approach for intensive permanent farming practices (Belloso 2008). In some regions, the construction of drainage and diking systems to prevent flooding interrupts the transfer of new materials from rivers to their floodplains, disrupting the natural cycle of the ecosystem. This can lead to a floristic change and modifications in the plant species cover, that are associated with alterations in the hydrologic cycle (Kalesnik *et al*. 2015). At the regional level, these practices can result in a decrease of the buffering capacity of the excess of water and a consequent change in plant structure (Bó *et al*. 2010). Furthermore, the presence of livestock and grazing induces changes in species richness, diversity, and dominance (Haretche & Rodríguez 2006). An intensification of grazing can reduce vegetal biomass by increasing erosion or salinity levels and decrease ecosystems productivity (Morris & Reich 2013).

When all land masses are considered, the South American wetlands constitute the vastest in the biosphere. Drainage basins of large rivers represent the biggest area occupied by these environments and over 80% can be found in warm climates (Baigún *et al*. 2008). Among these, the Uruguay River basin is one of the main wetlands systems in South America. The southern portion of this basin is located near a corridor that exhibits great human intervention. Therefore, preserving this part of the river floodplain would be important for mantaining vital ecological functions, such as biodiversity and gene pool of rare species from these systems. The lower Uruguay River is surrounded by large wetlands whose flooding regime can be evidenced by the presence of several plant species with high resistance to the changing conditions that dominate the area. However, few studies have focused on the distribution and structure of these plant communities and the impact of different alterations in the area (Di Persia & Neiff 1986).

When considering the importance of wetlands as a source of water supply for human settlements and for the development of several ecological processes (Keddy *et al*. 2009, Mitch & Gosselink 2007), it is crucial to understand the effect that different alterations may have on these environments. Identifying and describing spatial patterns of vegetation is essential to study wetlands function, while analyzing the effect of disturbances may serve as a starting point for the development of conservation plans (Paruelo *et al*. 2004).

The main goal of this study is to characterize the herbaceous plant communities associated with the final portion of the Uruguay River flood plain, focusing on the agriculture and livestock impacts that these communities may suffer. Our main hipotesis is that communities developing in modified areas exhibit different structure and composition patterns with respect to less-modified communities, and suffer ingression of exotic and invasive plant species that change theirs ecological attributes. In particular, we aim to analyse the plant structure and composition in both modified and less-modified areas and to describe the attributes of the associated plant communities.

Material and Methods

Study area

The landscape of the Uruguay River basin is the result of marine ingression and regression processes occured during the mid Holocene, superimposed by current fluvial processes. Both phenomena combined generated the pattern of marine landforms and flood plain environments seen today (Pereyra *et al*. 2002; Cavallotto *et al.* 2005). This basin comprises scrublands, forests, dunes and halophyte fields (Burkart 1957, Kalesnik *et al*. 2009a, Quintana *et al*. 2009; Aceñolaza *et al.* 2014). According to the ecoregions classification (Olson *et al.* 2001) the studied area is part of the Paraná flooded savanna, whose southern extreme reaches the Pampas phytogeographic unit considered in the traditional Argentinean biogeographic schemes (Brown & Pacheco 2006, Burkart *et al*. 1999, Cabrera 1976).

The Paraná flooded savanna is rich in flora and fauna that is not present in the surrounding regions. The presence of large water bodies generates a humid atmosphere that mitigates extreme daily and seasonal temperatures. This allows for the local presence of communities and species typical of the humid subtropical regions which, at a more global scale, are found further northeast.

The present study focused on lowlands of two farms (site 1 and site 2) located on the banks of the Uruguay River (Gualeguaychú, Entre Ríos, Argentina) (Fig. 1). The area is placed in the climate region *Cfa* based on the Köppen-Geiger classification system (Peel *et al*. 2007), exhibiting temperate climate, year-round precipitations, and average temperature of the warmest month above 22 ºC. However, during the year of sampling (2008), the Entre Ríos province suffered extreme drought conditions, with limited precipitations in terms of the historical average, low humidity and, therefore, high rate of evapotranspiration (INTA 2008).

Site 1 is located at the south of Gualeguaychú (centered location 33º 20’ S, 58º 28’ W) (Fig. 1), spanning over 10 km of riverbank. This site is surrounded by a 3 m high artificial embankment to prevent flooding. The enclosed surface area of 1 581 ha contains 0.6 to 0.8 heads of cattle per ha. Environments within the embanked portion of land have also been affected by the use of rollers. This technique consists on passing a metal cylinder filled with water that crushes the original vegetation and stirs the soil (Anriquez *et al*. 2005). This site also includes 206 ha of non-embanked land, composed of vast native scrublands and grasslands. Site 2 is situated north of the town of Gualeguaychú (centered location 32º 54’ S, 58º 11’ W) (Fig. 1). It comprises 30 km of riverbank and 9 844 ha of a mosaic of wetlands, including vast scrublands, floodable grasslands, and marshes.

Data collection

Considering a previous zoning and landscape units’ description (Kalesnik *et al.* 2009a, Quintana *et al*. 2009), field surveys were carried out in lowlands dominated by herbaceous vegetation within the two sites. Between March and May 2008, a random stratified sampling was performed in 72 plots (1-36 site 1 and 37-72 site 2). Out of the total number of plots, 16 were developed in anthropically modified environments. Plant species were sampled in each 5x5 m plot and assigned an abundance-cover value according to the modified Braun Blanquet scale (Müeller-Dumbois & Ellenberg 1974). Geographical coordinates of each plot were registered. Species lifeform type was assigned according to Barkam’s (1988) classification and Zuloaga *et al.* (2008).

Numerical analyses

Detrended correspondence analysis (DCA) was performed to detect ordination patterns of plots and species using CANOCO for Windows ver. 4.5 (Ter Braak & Smilauer, 1998). Plant species associations were studied using Two-way indicator species technique (TWINSPAN) (Hill & Smilauer, 2005). For each group, relative importance of species was estimated considering mean cover (MC) and relative frequency (RF). MC was calculated as the mean value of cover for each species, normalized by the total number of plots from each group. RF was the total number of plots within each group where the species was identified, relative to the total number of plots from each group. The ecological attributes considered were richness (S), diversity (H) and evenness (J). Biological diversity was estimated with the Shannon–Wiener index (Magurran, 1988). Normality of data was tested using Shapiro–Wilk test (Shapiro & Wilk 1965). A One-Way Analysis of Variance (ANOVA) was used to test differences in the attributes between communities, followed by the *Tukey* method of multiple comparisons when significant differences were found. Mean richness values did not meet the normality assumption and were, therefore, log transformed (MLS). All statistical analyses were performed using the XLSTAT software V.7.5.2 (2007).

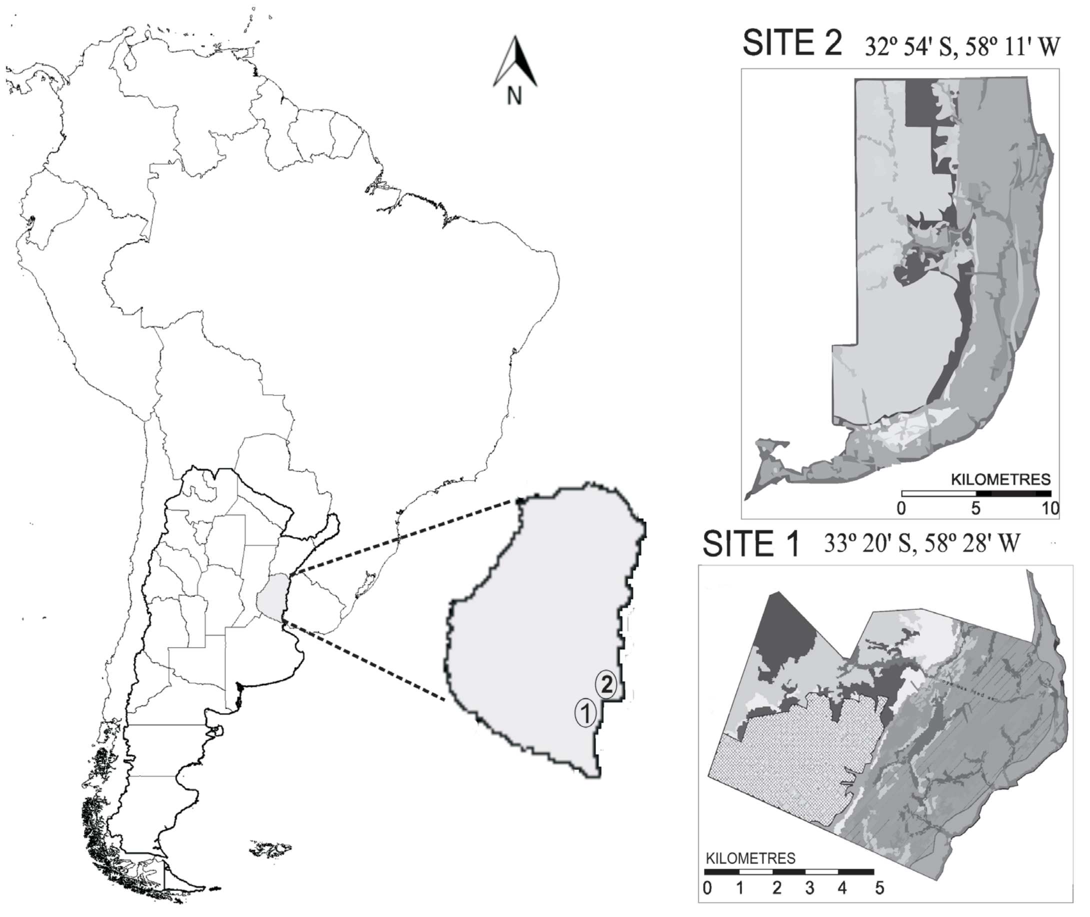

Fig. 1. Study area. Sites 1 and 2 detailed maps were taken from Kalesnik *et al.*2009a and Quintana *et al.* 2009 respectively.

Results

Classification analysis

A total of 270 species were found in the study area (including species with MC and RF < 5%) (Tab. 1). Six groups of plots were identified based on classification (Tab.1). Group 1 was dominated by *Coleataenia prionitis* (Nees) Soreng, forming grasslands of up to 2 m high. *Hymenachne grumosa* (Nees) Zuloaga was found among accompanying species (Tab. 1). The dominant species in group 2 was *Schoenoplectus californicus* (C. A. Mey.) Soják. Among secondary species found in this group were *Mikania micrantha* Kunth and *Polygonum punctatum* Eliott. Group **3** was exclusively formed by plots that develop in heavily modified environments, with presence of livestock and use of rollers within the dyque. Two plots within this group correspond to dry watercourses with low to null water flow due to the disruption of the riverbeds by the dyque. Abundant species in group 3 were mostly low herbaceous plants, such as *Alternanthera sp.* Forssk*; Cynodon dactylon* (L.) Pers.; *Eleocharis bonariensis* Nees; *Eupatorium hecatanthum* (D.C.) Baker and *Galium richardianum* (Hook. & Arn.) Walp. None of these species were dominant. Presence of common weeds such as *Solanum glaucophyllum* Desf., *M. micrantha,* and *Conyza bonariensis* (L.) Cronquist (Aceñolaza *et al*. 2011, Burkart 1969, Day *et al*. 2012, Lallana 2005, Walker *et al.* 2012) was also common in this group. Group 4 exhibited an herbaceous and an arboreous strata.

The first was dominated by *Scirpus giganteus* Kunth and the second by *Erythrina crista-galli* L.. Both species are very common in floodable areas Burkart (1957). As accompanying species were *M. micrantha; Sesbania punicea* (Cav.) Benth.*;* *Equisetum giganteum* L. and *Pfaffia glomerata* (Spreng.) Pedersen. Group 5 was dominated by *H. grumosa,* with *Carex chilensis* Duperrey; *E. crista-galli; Mimosa bonplandii* (Hook. & Arn.) Benth.; *G. richardianum* and *Paspalum haumanii* Parodi as attendant species. Group 6 showed two dominant species: *Cyperus giganteus* Vahl and *H. grumosa*, with *Polygonum stelligerum* Cham as secondary species (Tab. 1).

Ordination analysis

The groups found in Table 1 were in general also discriminated by the ordination analysis (Fig.2). The first two axes of the DCA explained ~13% of the variance. Ordination along axis 1 (eigenvalue: 0.916) may be attributed to the flooding preferences of the more abundant species of each group (Fig. 2). Therefore, groups 2 and 4 were placed on the positive end of the axis. Centrally positioned were groups 3, 5, and 6. Environments less liable to flooding comprised group 1 and were placed on the axis end nearest to zero, together with some plots of group 3 which corresponded to modified environments. Ordination of the plots along Axis 2 (eigenvalue: 0.774) does not show a pattern related to an environmental variable.

Attributes

Groups 1, 3, and, 4 exhibited the highest S values, with MLS significantly different from group 2 (*P*=0.001). Groups 5, and 6 did not show significant differences from the rest of the groups in MLS (Table 2). Group 2 showed the lowest H values and group 3 the highest (*P*=0.013). The latter also exhibited the highest J, even though this attribute was not significantly different between any of the groups (*P*=0.075).

Discussion

As the interest in the role of wetlands in biodiversity conservation and water supplies has become increasingly important, studies concerning the structure of these ecosystems and the alterations they suffer are essential. In this study we considered two sites in the southern portion of the Uruguay River floodplain, to identify and characterize the consequences of the human intervention that these wetlands undergo.

The results obtained suggest that the composition and structure of the herbaceous communities analyzed respond, not only to the natural environmental conditions, but also to the great human disturbances in the area. The plots that develop in highly disturbed environments were almost all gathered in the same community (group 3), which clearly differentiated from the rest of the groups in composition and structure. Is to be noted that the modifications were applied in different ways and intensity along the embanked area (cattle farming, roller use or both simultaneously). Despite that, almost all these plots grouped within the same community, resulting in a more homogeneous environment. To the contrary, communities with no apparent disturbances were distinguishable from each other in composition and structure (Table 1, Fig. 2). The distribution of both dominant species and biological types in undisturbed areas is strongly associated to the natural hydrological regime of the region (Morandeira *et al*. 2011).

The plant associations that develop in modified environments exhibited higher diversity and mean Log richness values. This could be due to an increase in the cover of ruderal and disturbance-resistant species (e.g. *G. richardianum*; *E. bonariensis*; *S. glaucophyllum; M. micrantha; P. distichum* and *C. bonariensis*) as a result of changes in the hydrological regime (Mitch & Gosselink 2007). Also, introduced and adventitious species were only present in this group or with higher MC values than in less- modified areas (Tab. 1). The use of rollers which flatten the original plant cover and stir the soil, and the livestock farming within embanked systems could have favored the settlement of these species that are typical of the Pampa grasslands ("pampeanization") (Bó *et al*. 2010; Morris & Reich 2013). The dry watercourses that are included in this group had marsh vegetation but also terrestrial plant species, suggesting that they are going through a succession process. This alteration could also lead to changes in the neighboring areas, since watercourses give rise to a large number of internal topographic gradients (Stevaux *et al*. 2013).

Table 1. Relative frequency and mean cover of species in each of the groups determined by TWINSPAN. Species with MC*RF < 5% are not shown.

Family	Species			G1 (N=12)		G2 (N=8)		G3 (N=14)		G4 (N=8)		G5 (N=15)		G6 (N=15)	
		LF	O	MC	RF	MC	RF	MC	RF	MC	RF	MC	RF	MC	RF
Alismataceae	*Echinodorus grandiflorus* (Cham. & Schltdl.) Micheli	LH	N	0.83	0.83	0.25	0.25	0.29	0.50			0.12	0.40	0.35	0.27
Alismataceae	*Sagittaria montevidensis* Cham. & Schltdl.	LH	N			0.64	0.25			0.64	0.25	0.67	0.67	0.70	0.13
Amaranthaceae	*Alternanthera ficoidea* (L) Sm.	LH	N						1.25	0.21					
Amaranthaceae	*Alternanthera sp*. Forssk	LH	N						3.57	0.50					
Amaranthaceae	*Pfaffia glomerata* (Spreng) Pedersen	LH	N								4.56	0.25	0.37	0.40	
Apiaceae	*Hydrocotyle bonariensis* Lam.	LH	N	0.44	0.33	0.38	0.38	0.38	0.29	0.44	0.38	0.23	0.13	0.67	0.67
Asteraceae	*Calyptocarpus biaristatus* (DC) H.Rob.	LH	N	0.29	0.17					0.13	0.13	0.27	0.13		
Asteraceae	*Conyza aff. bonariensis* (L) Cronquist	LH	N	0.43	0.17			2.67	0.14			0.30	0.27		
Asteraceae	*Enydra anagaliis* Gardner	LH	N				0.38	0.13	0.57	0.14					
Asteraceae	*Erechtites hieraciifolius* (L.) Raf. ex DC. var *cacalioides* (Fisch. Ex Spreng.) Griseb.	LH	A	0.42	0.83			3.32	0.14						
Asteraceae	*Eupatorium hecatanthum* (DC.) Baker	LH	N					9.19	0.50	0.13	0.13	0.33	0.67		
Asteraceae	*Mikania micrantha* Kunth	C	N	0.43	0.17	8.75	0.38	0.76	0.50	9.82	0.75	1.97	0.47	0.87	0.33
Asteraceae	*Pluchea sagittalis* (Lam.) Cabrera	LH	N					0.25	0.36	0.13	0.13	0.13	0.13		
Asteraceae	*Xanthium cavanillesii* Schouw	B	A					2.75	0.57	0.25	0.25			0.67	0.67
Asteraceae	*Symphyotrichum graminifolium* (Spreng.) G.L. Nesom	LH	N					0.71	0.36	0.13	0.13	0.67	0.67		
Cactaceae	*Rhipsalis lumbricoides* (Lem.) Lem. ex Salm-Dyck	C	N							0.19	0.50	0.34	0.13		
Cannaceae	*Canna glauca* L.	LH	N							0.75	0.25	0.20	0.67		
Capparaceae	*Cleome trachycarpa* Klotzch ex Eichler	LH	N					2.00	0.21						
Commelinaceae	Commelinaceae	LH	N							0.75	0.25				
Convolvulaceae	*Aniseia argentina* (N.E.Br.)O´Donell	C	E											0.70	0.13
Cucurbiatceae	*Cayaponia bonariensis* (Mill.) Mart.Crov.	C	N					0.71	0.71	0.63	0.13	0.47	0.20	0.13	0.13
Cyperaceae	*Carex chilensis* Brongn. ex Duperrey	GH	N	0.43	0.17			0.47	0.36	0.13	0.50	14.77	0.67	0.10	0.20
Cyperaceae	*Cyperus aff haspan* L.	EH	N							3.13	0.25				
Cyperaceae	*Cyperus giganteus* Vahl	EH	N	0.83	0.83	0.38	0.13	2.54	0.29	1.00	0.25	0.17	0.47	35.67	1.00

Family	Species			G1 (N=12)		G2 (N=8)		G3 (N=14)		G4 (N=8)		G5 (N=15)		G6 (N=15)	
		LF	O	MC	RF	MC	RF	MC	RF	MC	RF	MC	RF	MC	RF
Cyperaceae	*Cyperus sp* 1	EH	N			0.25	0.50								
Cyperaceae	*Cyperus sp* 2	EH	N									0.40	0.13		
Cyperaceae	*Cyperus virens* Michx.	EH	N	0.43	0.25	0.13	0.25	0.73	0.29			0.67	0.67		
Cyperaceae	*Eleocharis bonariensis* Nees	EH	N	3.42	0.50			11.71	0.50	0.13	0.25	0.20	0.67		
Cyperaceae	*Eleocharis sp* 1	EH	N							0.44	0.25	0.33	0.67		
Cyperaceae	*Eleocharis sp* 2	EH	N	0.84	0.25	0.38	0.25					0.67	0.67		
Cyperaceae	*Eleocharis sp* 3	EH	N	1.54	0.33	0.50	0.50								
Cyperaceae	*Rhynchospora corymbosa* (L.) Britton	GH	N	0.63	0.83	0.25	0.25	0.36	0.71			1.17	0.20	2.53	0.20
Cyperaceae	*Schoenoplectus californicus* (C.A. Mey.) Soják	EH	N			61.25	1.00	0.43	0.29			0.27	0.13	0.47	0.20
Cyperaceae	*Scirpus giganteus* Kunth	GH	E					0.71	0.14	63.50	1.00				
Equisetaceae	*Equisetum giganteum* L.	EH	N							1.88	0.75				
Euphorbiaceae	*Euphorbia serpens* Kunth	LH	N						0.54	0.36					
Euphorbiaceae	*Sapium haematospermum* Müll.Arg.	T	N					0.14	0.14	0.38	0.13	0.67	0.13		
Fabaceae	*Crotalaria micans* Link	LH	N	0.50	0.17										
Fabaceae	*Erythrina crista-galli* L.	T	N	0.83	0.83			0.36	0.14	27.56	0.75	4.97	0.47	0.60	0.20
Fabaceae	*Mimosa bonplandii* (Gillies ex Hook. & Arn.) Benth.	B	E	0.17	0.50			0.25	0.14			2.17	0.67	1.17	0.40
Fabaceae	*Sesbania punicea* (Cav.) Benth	B	E	0.83	0.83	0.38	0.25	5.25	0.43	5.31	0.50	0.67	0.20	0.67	0.67
Lamiaceae	*Condea undulata* (Schrank) Harley & J.F.B. Pastore	LH	N							0.38	0.38				
Malpighiaceae	*Stigmaphyllon bonariense* (Hook. & Arn.) C. E. Anderson	C	N	0.42	0.83					0.13	0.25	0.22	0.27		
Malvaceae	*Pavonia hastata* Cav.	LH	N	0.67	0.17										
Onagraceae	*Ludwigia peruviana* (L.)Hara	LH	N							0.63	0.63	0.72	0.33	1.27	0.47
Onagraceae	*Ludwigia bonariensis* (Micheli) H. Hara	LH	N	0.43	0.17	1.31	0.25								
Oxalidaceae	*Oxalis sp*	LH	N	0.63	0.58										
Phyllanthaceae	*Phyllantus sellowianus* (Klotasch) Mull. Arg.	B	E									5.53	0.13		
Poaceae	*Coleataenia prionitis* (Nees) Soreng	GH	E	65.67	1.00										

Family	Species			G1 (N=12)		G2 (N=8)		G3 (N=14)		G4 (N=8)		G5 (N=15)		G6 (N=15)	
		LF	O	MC	RF	MC	RF	MC	RF	MC	RF	MC	RF	MC	RF
Poaceae	*Cynodon dactylon* (L.) Pers.	GH	I	0.92	0.25	0.13	0.13	12.68	0.43						
Poaceae	*Hymenachne grumosa* (Nees) Zuloaga	GH	N	4.63	0.50	0.13	0.25	0.71	0.71	0.50	0.50	5.77	1.00	36.23	0.80
Poaceae	*Paspalum aff denticulatum* Trin.	GH	N					2.54	0.29						
Poaceae	*Paspalum aff distichum* L.	GH	N					2.54	0.29						
Poaceae	*Paspalum haumanii* Parodi	GH	N									7.77	0.13		
Poaceae	*Paspalum urvillei* Steud.	GH	N	0.83	0.83					1.38	0.38				
Poaceae	Poaceae 1	GH	N									2.43	0.13		
Poaceae	Poaceae 2	GH	N					2.17	0.14						
Poaceae	*Polypogon monspeliensis* (L.) Desf.	GH	A					6.54	0.14						
Poaceae	*Setaria sp*	GH	N	0.33	0.33										
Poaceae	*Zizaniopsis bonariensis* (Balansa & Poitr.) Speg.	GH	N					9.21	0.14					0.27	0.13
Polygonaceae	*Polygonum aff acuminatum* Kunth	LH	N											0.40	0.13
Polygonaceae	*Polygonum punctatum* Elliot	LH	N	0.83	0.17	2.50	0.75	1.19	0.71	0.19	0.50	1.47	0.53	0.73	0.27
Polygonaceae	*Polygonum stelligerum* Cham.	LH	E			0.13	0.25					0.91	0.33	2.34	0.53
Polypodiaceae	*Microgramma mortoniana* de la Sota	C	N							1.13	0.38	0.68	0.27		
Rubiaceae	*Cephalanthus glabratus* (Spreng) K. Schum	B	N	0.17	0.17	0.13	0.13			0.75	0.25			0.57	0.40
Rubiaceae	*Galium richardianum* (Gillies ex Hook & Arn) Endl. Ex Walp.	LH	E	0.83	0.83			7.68	0.93			4.67	0.33		
Solanaceae	*Solanum glaucophyllum* Desf.	LH	N					0.15	0.50			0.11	0.33	0.67	0.67
Urticaceae	*Boehmeria cylindrica* (L.) Sw.	LH	N							0.38	0.38				
Verbenaceae	*Verbena litoralis* Kunth	LH	N							0.13	0.13	0.47	0.20		
Vittaceae	*Cissus palmata* Poir.	C	N	0.17	0.17	0.63	0.13	0.71	0.71	0.13	0.13	0.69	0.40	0.23	0.67

LF Life form, *O* origin, *RF* relative frequency, *MC* mean cover. *T* tree, *B* bush, *C* creeper, *H* herbaceous, *E* endemic, *N* native, *A* adventitious, *I* Introduced (Following Barkman 1988, Zuloaga *et al*. 2008)

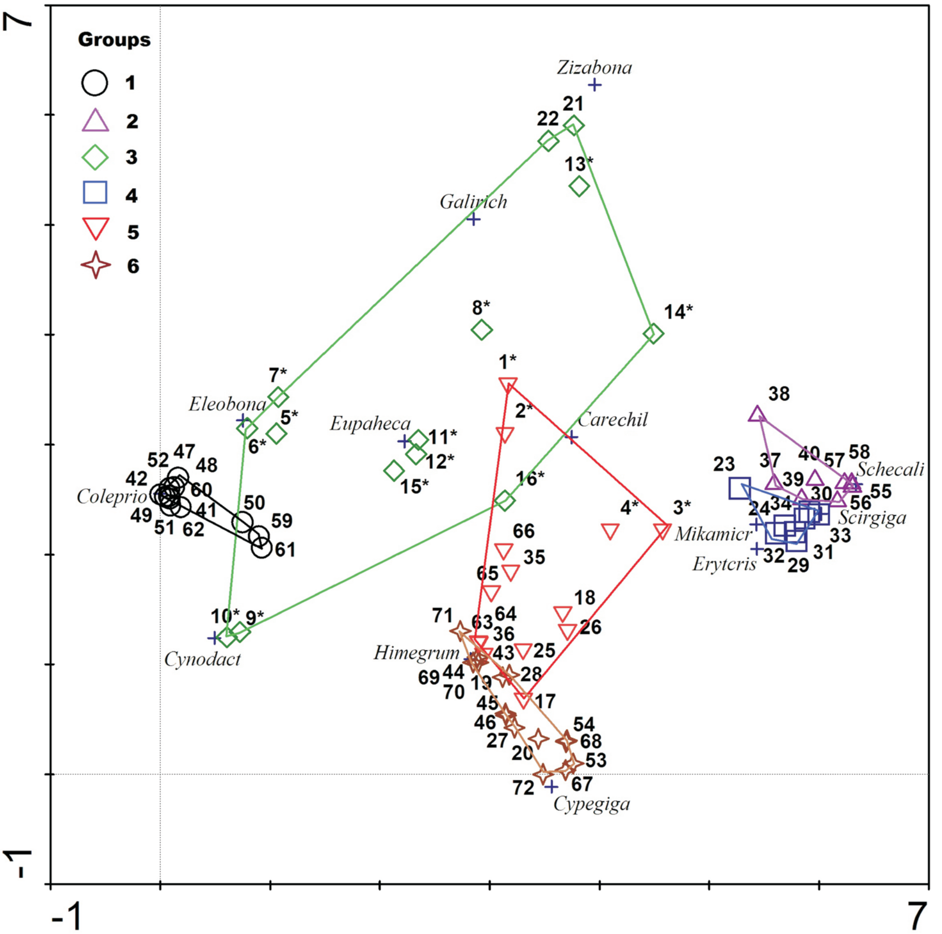

Fig. 2. Ordination of plots along the two axes of the DCA and classification using TWINSPAN. Squares, diamonds, triangles and circles indicate plots for each group and their respective names; crosses reference the principal species in the ordination; 1-6 are the group names; groups are separated by continuous lines. Coleprio: *Coleataenia prionitis*, Carechil: *Carex chilensis*, Cynodact: *Cynodon dactylon*, Cypegiga: *Cyperus giganteus*, Eleobona: *Eleocharis bonariensis*, Eupaheca: *Eupatorium hecathanthum*, Erycris: *Erythrina crista-galli*, Galirich: *Gallium richardianum*, Himegrum: *Hymenachne grumosa*, Mikamicr: *Mikania micrantha*, Scirgiga: *Scirpus giganteus*, Schecal: *Schoenoplectus californicus*, Zizabona: *Zizanopsis bonariensis.*

The less-modified community dominated by *E. crista-galli* showed the second highest diversity value, even though not significant. This may be due to the capacity of *E. crista-galli* to serve as substrate for a number of epiphyte and creeper species (De Andrade Kersten & Kuniyoshi 2009; Giudice *et al.* 2011) resulting in the presence of several accompanying taxa. In addition, the ability of this species to grow in different soil types makes it the only tree that establishes plant associations in lowlands of the studied area (Burkart 1957, Kandus 1999). Grasslands dominated by *H. grumosa* (groups 5 and 6) were located in intermediate areas in terms of flooding preferences, in accordance with earlier studies (Kandus *et al*. 2002). Group dominated by *S. californicus*, exhibited the lowest mean log richness and diversity, as it is expected for this kind of community in natural conditions (Burkart 1957). Grasslands dominated by *C. prionitis* (group 1) developed in soils less prone to flooding, on hillocks, and on an old tidal plain showing signs of previous rice farming practices.

Table 2. Ecological attributes of the identified groups (mean ± standard deviation). *P* values of ANOVA test are showed. In bold, attributes that exhibited significant differences. N is the number of plots and between brackets the number of plots in modified environments. MS= mean richness, MLS= mean log richness, MH= mean diversity, MJ= mean eveness.

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	*P*
N	12(0)	8(0)	14(14)	8(0)	15(4)	15(0)	
MS	16.25 ± 4.45	7.75 ± 3.20	16.86 ± 5.49	18.00 ± 8.88	15.67 ± 9.18	10.27 ± 3.69	
MLS	**1.20 ± 0.12[a]**	**0.85 ± 0.20[b]**	**1.21 ± 0.14[a]**	**1.19 ± 0.29[a]**	**1.11 ± 0.29[ab]**	**0.99 ± 0.15[ab]**	**0.001**
MH	**0.80 ± 0.45[ab]**	**0.63 ± 0.52[b]**	**1.35 ± 0.39[a]**	**1.19 ± 0.61[ab]**	**1.15 ± 0.69[ab]**	**0.88 ± 0.38[ab]**	**0.013**
MJ	0.30 ± 0.17	0.29 ± 0.23	0.49 ± 0.15	0.40 ± 0.18	0.42 ± 0.19	0.38 ± 0.16	0.075

[a] Significantly different from [b] (P<0.05) Tukey

Communities localized in less-modified areas are simple in terms of their low richness and are characterized by the dominance of a few species but, from a floristic and environmental point of view, they form a heterogeneous mosaic (Kandus *et al*. 2003). To the contrary, it seems to be a homogenization of the environment within the communities that suffered human disturbances. In most habitats, plant communities have great influence on the distribution and interactions of the native fauna. Also, it has been documented a positive relationship between vegetation-shaped habitat heterogeneity and animal species diversity, at both local and regional scales (Ricklef & Schluter 1993, Tews *et al*. 2004). Therefore, the modification of the local plant communities has important implications on the native fauna.

It can be concluded that herbaceous communities developing in modified environments suffer changes in structure and in their main attributes (richness and diversity) associated with the type of modifications conducted in the area. Conservation of herbaceous communities in less-modified environments is of vital importance since they represent the typical plant associations of the natural landscape without interference by invasive exotic species, within a region highly fragmented by human activities (Kalesnik & Malvárez 2003; Kalesnik *et al*. 2009b). Alteration of these communities could not only impact wetlands values and functions but also those of the neighboring environments. In this regard, the analyzed communities serve a primary role in the conservation of regional biodiversity and should be included in natural reserve projects or other actions related to the conservation of biological diversity they represent. From a biogeographical standpoint, the studied communities share traits with the Paraná River system (e.g. composition, structure, and geoforms) constituting a complex system interconnected since the mid Holocene (Pereyra *et al*. 2002).

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