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Diversity of anurans across agricultural ponds in Argentina

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Abstract. We examined the anuran diversity of 31 ponds (30 located on the border of soybean cropland and one within a protected forest) in mid-western Entre Ríos Province (Argentina). Moreover, each species found was characterised with respect to its vertical location. Using principal component (PCA) and canonical correspondence analyses (CCA) we quantified associations between species diversity and habitat and spatial variables. A total of 21 anuran species belonging to four families (Microhylidae, Bufonidae, Leptodactylidae and Hylidae) were detected in ponds surrounded by soybean croplands. PCA generated three principal components, which together explained variation in anuran diversity across the agricultural ponds and control site. Negative values of PC-1 described the smaller ponds with narrower hedgerow and monospecific shore vegetation. PC-2 had high loading on pond depth, and PC-3 had negative loading on air temperature. CCA showed a very strong association between the two data sets. We found all guilds related with pond area. Indeed, we found that arboreal species were recorded in large ponds with higher values of shore vegetation index and presence of wider hedgerow. Moreover, a higher number of terrestrial species was found to relate to large pond areas and greater shore vegetation diversity. Finally, aquatic species were related to pond area, shore vegetation index and depth. Anuran diversity across agricultural ponds of mid-western Entre Ríos Province can be affected by local habitat factors such as reduction in pond size and depth, shore vegetation richness, width of hedgerow and air temperatures. Management of anurans to reverse recent declines will require defining high-quality habitat for individual species or group of species, followed by efforts to retain or restore these aquatic habitat. The maintenance of shore vegetation of ponds and hedgerows may increases the number of species and diversity of anurans within agricultural landscapes.

Introduction

The causes of amphibian declines are under investigation, but emerging evidence indicates that loss of habitat as a result of agricultural development may be contributing to regression of anuran diversity in some locations (Bishop and Pettit 1992; Bonin et al. 1997; Bridges 1999; Hazell et al. 2001; Lajmanovich et al. 2002, 2003; Storfer 2003). Management of amphibian populations to reverse this phenomenon will require defining high-quality habitat for individual species or group of species, followed by efforts to retain or restore these habitats (Knutson et al. 1999).

The conversion of forest to agricultural land is occurring at rapid rates in many Neotropical areas. These land-cover trends have spurred research to investigate the role that agroecosystems play in providing habitat for Neotropical organisms and in the conservation of biodiversity (e.g. Lips 1998; Ricketts et al. 2001; Petit and Petit 2003). In the mid-east Argentina, traditional agriculture was replaced by a more specialised agriculture aimed at large scale production with glyphosate-tolerant-soybean (*Glycine max* L.) as the dominant crop. This new agriculture has led to the expansion of cultivated areas, thus exerting an increasing pressure on uncultivated portions of the land and wildlife survival. Forest habitat in the agricultural landscapes have been reduced and fragmented into numerous small plots, and the hedgerows, which often represent the only remaining corridors for wildlife between these plots, are also being critically threatened. Indeed, many of the aquatic habitats that are crucial for anuran reproduction and survival have been greatly altered to the point where existing amphibian populations may be dependent on altered wetlands or ephemeral ponds imbedded within or around agricultural areas for their survival and reproduction (Peltzer and Lajmanovich 2001; Peltzer et al. 2003).

We studied the anuran diversity in ponds surrounded by soybean croplands in Entre Ríos Province (Argentina). Specifically, we asked the following questions: (1) what habitat and spatial variables are influencing anuran diversity from ponds surrounded by soybean croplands? (2) what are the ecological distributions of species (guilds) across agricultural ponds? (3) what conservation measures are suggested by these results? Answers to these questions are not only of ecological interest but also of practical significance for the future conservation management of anurans in agroecosystems.

Material and methods

Study area

The research took place in mid-western Entre Ríos Province, Argentina (31°44′S–60°31′W) (Figure 1). This region belongs to the pluvial district of Argentina with an average annual rainfall below 1000 mm and a mean annual temperature of 18 °C. The warmest months are September–March (24 °C average temperature), the coldest, April–August (10 °C). This region is located at the east boundary of the Paraná River course. Agriculture is the predominant land use in this region, covering more than 60% of its 2500 mil. ha. Most of the agricultural land is devoted to soy (40%) and corn and other cereal production (17%). The remaining area is covered by fluvial and semi-xeric forest (29%), and edge transition habitats (5%, abandoned farmland and border structures, such as hedgerows). Farmers frequently clear land parcels, whether fallow tracts or the forest, at an onset of the dry season;

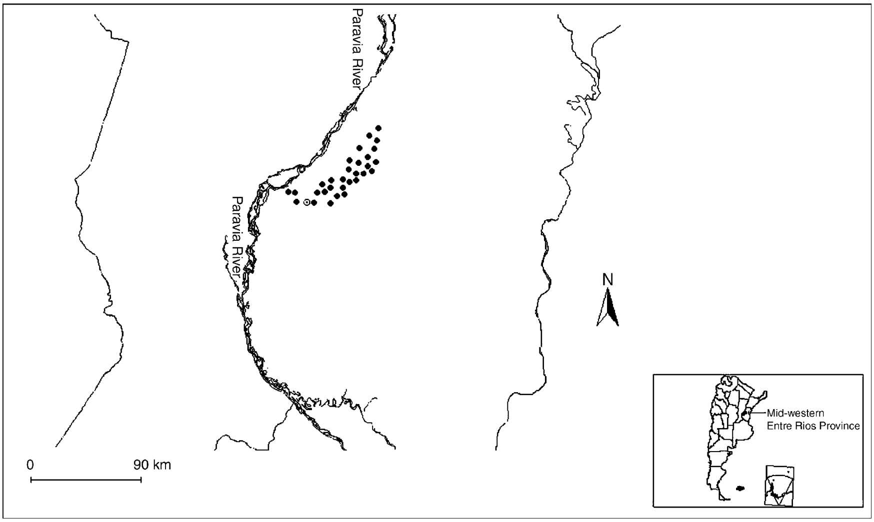


Figure 1. Location of the mid-western Entre Ríos Province with inset maps showing its location in Argentina and sampling sites within study area. • = agricultural ponds and ⊙ = control site.

usually in August. In September, the dried debris is burned and soybean planting occurs soon thereafter (usually in November). It is important to note that few farmers leave hedgerows with scarce width (> 1 m) of natural vegetation. The vegetation in these narrow hedgerows is often maintained at the herbaceous or shrubby stage through mowing or burning, but it is more heterogeneous than that of the structurally uniform cropland. This practice stems from the farmers' belief that such management diminishes the risk of hedgerows becoming refuges for pest species. The herbaceous vegetation is mostly characterised by a mixture of sown grass species (*Cynodon dactylon*, *Lolium multiflorum* and *Setaria geniculata*) with a high content of clover (*Trifolium repens*) and goldenrod (*Solidago chilensis*). The predominant shrubby vegetation is covered by *Ligustrum sinence*, *Aloysia gratisima*, *Bachharis dracunculifolia* and *B. salicifolia*.

Field survey

Landsat images and serial aerial photographs (first order to fifth order at a scale 1:50.000 – Brigada Aérea Argentina at Paraná City of Entre Ríos Province) were used to select 31 ponds: one located within a protected semi-xeric forest (Control site, Natural Reserve 'Parque General San Martín') and 30 agricultural ponds (AP) surrounded by soybean croplands (Figure 1). For the selection of the agricultural ponds particular attention was paid to following features: (1) all ponds had water during the period studied, (2) the pond contained no significant gradients in altitude, and (3) all ponds were primarily temporary bodies of water. Cattails (*Typha latifolia*), willow (*Salix humboldtiana*), burhead (*Echinodorus grandiflorus*), pampas grass (*Cortaderia selloana*), duckpotatoe (*Sagittaria montevidensis*), smartweed (*Polygonum punctatum*), bulrush (*Schoenoplectus californicus*) and rush (*Juncus pallescens*) were the most common emergent vegetation in the ponds but there were no aquatic floating plants.

The pond areas ranged from 50 to 31,000 m^2. The surveys were conducted during the soybean-cropping period from November 2002 to March 2003. This period is coincident with the breeding activity of anuran in this region.

A number of search strategies were used at each pond to study anurans. Day and night surveys were conducted at each pond on the same day. During the day, surveys were undertaken to detect anuran egg masses and tadpoles. Egg masses that were unidentified in the field were raised in captivity. A fine-meshed net was used for tadpole samples. Night surveys included active searches to detect non-calling anurans and listening for calling male anurans. The nocturnal site searches began shortly after sunset (1900 h) and extended until midnight. This method is a combination of the visual encounter surveys of Crump and Scott (1994) and audio strip transects of Zimmerman (1994). Active site searches for anurans consisted of a randomly placed transect walked for 10 min, 1 m upslope from and parallel to the water's edge. Male anurans calling from up to 100 m from the edge were also recorded. Each species found was characterised with respect to its vertical location using Vallan's (2000) guild criteria, where (1) were species found on the ground (terrestrial); (2) floating in water or inhabiting marsh (aquatic); (3) inhabiting herbaceous, shrubby, or arboreal habitats (arboreal). Captured anurans were identified, photographed and then released. Unidentifiable specimens (larval or adult) were euthanized and fixed for later identification (ASIH et al. 2001). The specimens are held at the Instituto Nacional de Limnología (Peltzer and Lajmanovich – INALI Amphibian Reference Collection).

The variables

We recorded five habitat variables: pH (with Lovibond), air and water temperature (with a standard thermometer), maximum depth (with stick) and shore vegetation richness. Shore vegetation was identified and the vegetal richness for each site was gauged on a qualitative scale ranging from 1 to 5 (Coneza Fernandez Vitora 1997) where one was monospecific vegetation and five was very diverse vegetation. Moreover, we determined four spatial variables: pond area (m^2), interpond distance (in km), the distance (in km) to the pond located within a control site, and width of hedgerows (m). The last three variables were registered only for agricultural ponds.

Data analysis

Anuran diversity was calculated using Shannon's index (Shannon and Weaver 1949) for the period studied. Evenness was calculated using the criteria of Magurran (1987). A *t*-test (Hutcheson 1970, as provided in Zar 1984) tested for differences in anuran diversity between each agricultural pond and the control site. We calculated the similarity between survey sites in terms of the composition of anuran assemblages and habitat and spatial variables using the standardised Euclidean distance measure (Dalrymple 1988). The similarity values were used to construct a site-by-site similarity matrix for the 31 survey sites. We clustered the sites on the similarity of their anuran composition (richness and diversity) and habitat and spatial variables using the unweighted pair group method using the arithmetic averages (UPGMA) method (Sneath and Sokal 1973). Log transformations of the variables were performed to normalise distributions. These analyses were performed with the BIO-DAP diversity analyses package (Thomas 2000).

We used principal components analyses (PCA) to reduce 9 habitat and spatial variables to a smaller number of independent components and determine which variables contributed most to anuran diversity variation. Only principal components that produced eigenvalues greater than 1.0 were analysed. Correlations with an absolute value greater than 0.9 were considered extremely significant (Hair et al. 1979). Variables derived from PCA were used as the predictor (independent) variables: anuran diversity within a pond was the response (dependent) variable. Analyses were performed with the SYSTAT software (SYSTAT 1998) at the 5% significance level. We used canonical correspondence analysis (CCA) to analyse the association between habitat and spatial variables through a correlation matrix based on the anuran counts. One independent set was composed of habitat and spatial variables and the other dependent set was formed by the number per anuran species. This statistical test was carried out using MVSP software (Kovach 1999). In order for all variables to have the same influence on the distance calculation, the variables were standardised (Manly 1991).

Data on the ecological distribution of species (guilds) and the relationship with significant habitat or spatial variables derived from PCA were analysed by the Pearson's correlation test. The data were log transformed. In order to test the hypothesis that the proportion of species within the guilds (i.e. terrestrial, arboreal and aquatic) remains constant across pond communities (Wilson 1989), the presence–absence matrix was first converted into a contingency table such that each column represents a pond and each row represents a guild. According to the Guild Proportionality model, the relative number of species within each guild is predicted to remain fixed among ponds. We utilized a *C*-score co-occurrence index (Stone and Roberts 1990; Gotelli and McCabe 2002). The *C*-score is calculated for each species pair using the formula $(ri-S)$ $(rj-S)$ where ri and rj are the number of occurrences for species i and j and S is the number of co-occurrences. Null model analyses were conducted with ECOSIM 7.0 simulation software (Gotelli and Entsminger 2001).

Results

A total of 23 anuran species belonging to four families (Microhylidae, Bufonidae, Leptodactylidae and Hylidae) were detected at ponds surrounded by soybean croplands and the control site (Table 1). Anuran species found at ponds surrounded by soybean croplands and within the protected forest (control site) were *Elachistocleis bicolor*, *Bufo arenarum*, *B. paracnemis*, *B. fernandezae*, *Odontophrynus americanus*, *Leptodactylus ocellatus*, *L. chaquensis*, *L. latinasus*, *L. mystacinus*, *L. gracilis*, *Physalaemus biligonigerus*, *P. riograndensis*, *Lysapsus limellus*, *Hyla nana*, *H. pulchella*, *H. sanborni*, *Scinax nasicus*, *S. squalirostris* and *S. acuminatus*. Only *L. elenae* and *H. raniceps* were exclusively recorded at the pond located within the control site, and *Physalaemus albonotatus* and *Pseudopaludicola falcipes* only in agricultural ponds.

The most common species observed were *P. albonotatus*, recorded in 73.3% of the total ponds sampled surrounded by soybean croplands, following by *L. latinasus* (70%), and *Bufo paracnemis* (66.6%). Eggs and tadpoles in foam nests were recorded for *L. ocellatus*, *P. albonotatus*, and *P. biligonigerus*, whereas egg-deposition and larval development directly in water were recorded only for *Hyla pulchella*, *Scinax nasicus*, and *S. squalirostris*.

Species diversity among soybean agricultural ponds varied from 0.30 (AP 20) to 1.14 (AP 27), and evenness values oscillated between 0.90 and 1. The diversity value of the pond located within the protected forest was 1.27 and the evenness was 0.96 (Figure 2). The t-test showed significant differences between the diversity of each agricultural pond and the diversity of control site (in all cases, $t > 3.21$, $p < 0.001$). Similar results were observed in cluster analysis. This analysis, based on the species richness, diversity and habitat and spatial variables of the 31 survey sites, produced two groups (Figure 3). Group A was formed by agricultural ponds and was divided into two subgroups (1, grouped ponds with higher anuran richness and diversity; 2, clustered ponds with lower anuran richness and diversity). The pond located within protected forest (Control site: B) had a distant association with the former groups.

The PCA produced three components, which accounted for 95.61% of the variance in the raw data (Table 2). The first component (PC-1) accounted for 57.35% and was strongly correlated (<0.9) with pond area, width of hedgerows and shore vegetation. The second component (PC-2) showed strong positive correlation with pond depth and accounted for 27.57% of the variability. The third component (PC-3) explained 9.69% of the variation and was correlated with air temperature. Canonical correlation analysis (CCA) showed a very strong association between the two data sets, one set formed by anuran species (dependent variables) and another by habitat and spatial variables (independent variables) (Table 2, Figure 4a, b).

Table 1. Anuran richness in ponds surrounded by soybean croplands in mid-western Entre Ríos Province.

Anuran species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	CS	BH
Microhylidae																																
E. bicolor	–	–	+	–	–	+	+	+	+	–	–	+	+	–	–	–	+	–	–	–	+	–	+	+	–	+	–	–	–	–	+	T
Bufonidae																																
B. arenarum	+	–	+	+	+	+	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	+	T
B. paracnemis	–	–	+	–	+	–	+	–	–	+	+	+	+	+	+	–	+	+	–	+	+	+	+	–	+	+	+	+	+	–	+	T
B. fernandezae	+	+	–	+	–	+	+	+	+	–	+	+	–	–	–	–	–	+	+	–	–	+	–	+	–	–	+	–	+	–	+	T
Leptodactylidae																																
O. americanus	–	–	+	–	+	+	–	–	–	–	–	–	+	–	+	–	+	–	–	–	–	–	–	+	–	–	–	–	–	–	+	T
L. ocellatus	–	–	+	+	+	+	+	+	+	–	–	–	+	+	+	+	–	–	+	–	+	+	–	+	+	+	+	–	–	–	+	A
L. chaquensis	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	+	+	+	–	–	–	+	+	+	–	–	–	–	–	+	T
L. latinasus	–	+	+	+	+	+	+	–	–	+	–	+	+	+	+	–	+	+	–	+	–	+	+	+	+	+	+	+	–	+	+	T
L. mystacinus	+	+	–	+	+	+	–	–	–	–	+	–	–	–	+	+	+	–	–	–	+	–	–	+	+	–	–	+	+	+	+	T
L. elenae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	T
L. gracilis	–	–	–	–	–	+	–	+	+	–	–	–	–	+	–	+	–	+	–	–	–	+	+	–	–	+	+	–	+	–	+	T
P. albonotatus	–	–	+	+	+	+	+	+	+	+	–	–	+	+	+	+	+	–	+	–	+	+	+	+	+	+	+	–	+	+	–	A
P. biligonigerus	–	–	–	+	–	–	+	–	–	–	–	–	+	–	+	–	+	–	+	–	–	–	–	+	+	–	+	–	–	–	+	A
P. riograndensis	–	–	–	–	+	–	–	–	–	–	–	–	–	+	+	+	–	–	–	–	–	+	+	–	–	+	+	–	–	–	+	A
P. falcipes	–	–	+	–	–	+	+	–	–	–	–	–	+	+	–	+	–	–	+	–	–	–	–	+	–	+	+	–	–	–	–	A
Hylidae																																
L. limellus	–	–	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	A
H. nana	–	–	+	+	–	+	–	–	–	–	–	–	+	–	+	+	–	–	+	–	–	+	–	+	–	+	+	–	–	–	+	Ar
H. pulchella	–	–	+	+	+	–	–	–	–	–	–	–	–	+	+	+	+	–	+	–	+	+	+	–	+	–	+	–	–	–	+	Ar
H. sanborni	–	–	+	+	+	+	–	–	–	–	–	–	+	–	+	+	–	–	+	–	–	–	–	+	–	+	+	–	–	–	+	Ar
S. nasicus	–	–	+	+	–	–	–	–	–	–	–	–	–	+	+	+	–	–	–	–	+	–	+	+	+	–	+	–	–	–	+	Ar
S. squalirostris	–	–	–	–	+	–	–	–	–	–	–	–	+	+	+	+	–	–	+	–	–	–	+	–	–	+	+	–	–	–	+	Ar
S. acuminatus	–	–	+	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	+	–	–	–	+	Ar
H. raniceps	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	Ar
Diversity	1.3	0.9	2.5	2.2	2.2	2.4	1.9	1.6	1.7	1.0	1.0	1.3	2.4	2.2	2.4	2.4	1.9	1.5	2.1	0.6	1.9	2.0	2.1	2.4	2.2	2.3	2.6	1.1	1.0	1.0	2.9	
Richness	3	3	14	11	12	11	8	6	6	3	3	4	12	11	12	12	8	5	10	2	7	8	10	12	10	11	15	3	4	3	21	

(+) Presence, (–) absence. Overview of the anuran richness and guilds. With different numbers we listed the ponds. CS, control site; BH, biological habits; T, terrestrial; A, aquatic; Ar, arboreal species.

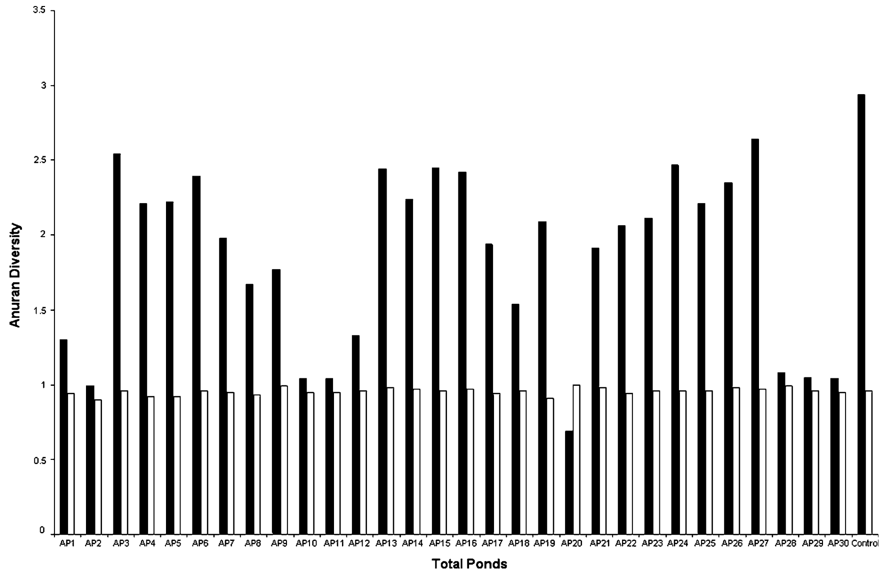


Figure 2. Anuran diversity (black bars) and evenness (white bars) across agricultural pond (AP) and control site.

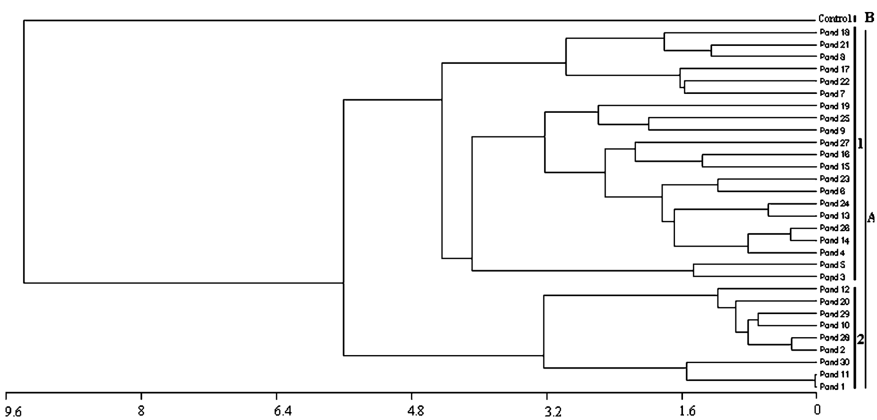


Figure 3. Cluster analysis of the 30 agricultural ponds and the control site examining the similarity of their anuran richness. AP: agricultural ponds.

The number of terrestrial species increased with increasing pond area (Pearson: $n = 31$, $r = 0.59$, $p < 0.01$) and with very-diverse vegetation (Pearson: $n = 31$, $r = 0.47$, $p < 0.01$). The number of aquatic anurans was dependent of both pond area (Pearson: $n = 31$, $r = 0.82$, $p < 0.01$), depth of ponds (Pearson: $n = 31$, $r = 0.80$, $p < 0.01$) and vegetation diversity index (Pearson: $n = 31$, $r = 0.88$, $p < 0.01$). The number of arboreal anurans was

Table 2. Principal component loadings for anuran diversity, habitat (air and water temperature, depth, pH and shore vegetation index) and spatial variables (pond area, width of hedgerows, distance to control site, interpond distance, and shore vegetation index) measured at 31 survey sites and results of a canonical correlation analysis between two sets of variables.

Variables	PC-1	PC-2	PC-3
Principal component analysis			
Habitat variables			
Air temperature	0.57	0.14	−0.79
Water temperature	0.84	−0.36	0.26
Depth	0.14	0.96	0.05
pH	0.57	−0.71	0.30
Shore vegetation index	−0.90	0.42	0.13
Spatial variables			
Pond area	−0.90	0.26	0.20
Distance to control site	0.85	0.46	0.22
Interpond distance	0.69	0.68	0.06
Hedgerow width	−0.91	0.21	0.09
Shore vegetation index	−0.90	0.42	0.13
Percentage of variance explained	58.35	27.57	9.69
Cumulative	58.35	85.92	95.61
Canonical correspondence analysis	Axis I	Axis II	Axis III
Species–environmental canonical correlation	0.919	0.916	0.855

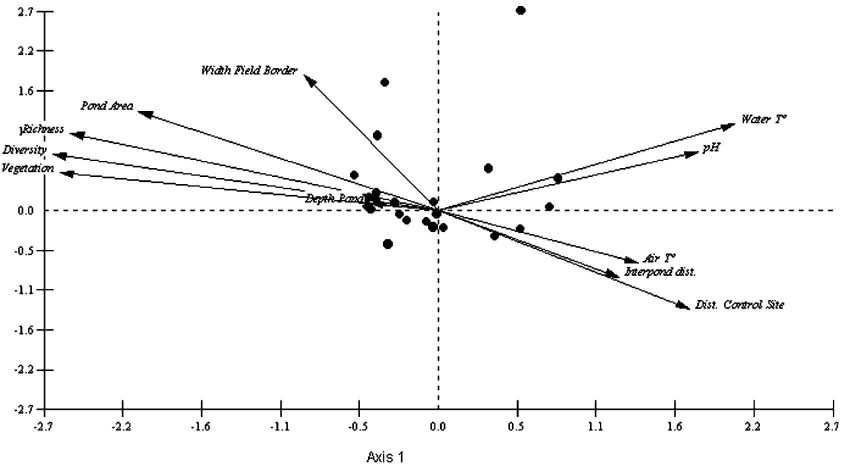
Notes: Variables with high positive or high negative values are underlined to indicate the variables that more or most contributed to anuran diversity variation across agricultural ponds and control site.

positively correlated with pond area (Pearson: $n = 31$, $r = 0.88$, $p < 0.01$), width of hedgerow (Pearson: $n = 31$, $r = 0.69$, $p < 0.01$), and shore vegetation index (Pearson: $n = 31$, $r = 0.80$, $p < 0.01$). The proportion of species within each guild varied greatly among pond assemblages (Figure 5). The *C*-score index was less than expected by chance. The observed *C*-score ranged from 40.9 for the terrestrial guild to 7.4 for the arboreal guild. The larger *C*-score values are shown more segregation between species within a guild.

Discussion

Spatial and temporal heterogeneity of the landscape is essential for maintenance of specifies diversity (Huston 1995), which depends on the regime of disturbances (Risser 1995; Turner et al. 1995; Gustafson 1998). Several studies have shown that agroecosystem instability is linked to the expansion of crop monocultures and the decline in local habitat diversity (Altieri 1994), with more disturbed sites generally having lower species richness (Bishop et al. 1999). We found that less abundant species (*Physalaemus albonotatus*, *Pseudopaludicola falcipes*), which do not occur in the protected forest (Lajmanovich and Peltzer 2001) have 'invaded' the ponds surrounding soybean crops and are commonly encountered in the soybean matrix, a similar situation also observed in other tropical and subtropical areas (Jansen 1986; Lawton et al. 1998;

(a)



(b)

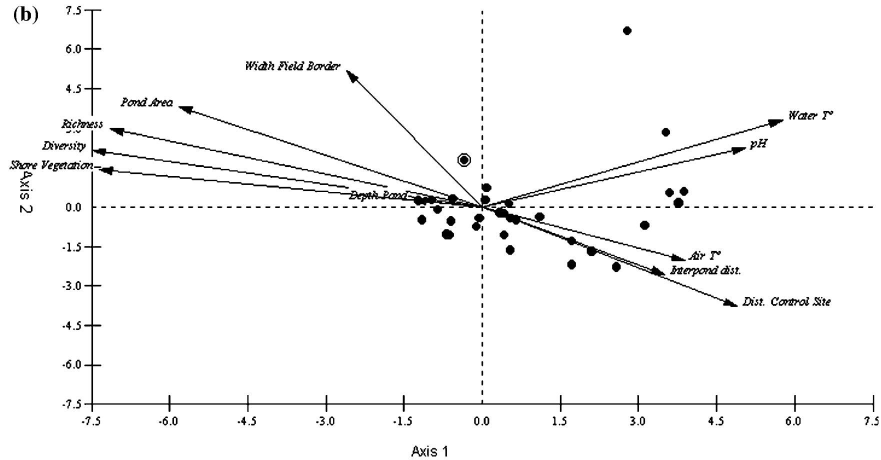


Figure 4. Plots of canonical correspondence analysis by species (variables, a) and ponds (cases, b). ⊙ = control site.

Gascon et al. 1999). These invading species may well be specialists of non-forested habitats. A substantial number of arboreal species (*H. pulchella*, *Scinax nasicus* and *S. squalirostris*) are capable of using ponds surrounded by soybean cultivation. We also suggest that an arboreal (*H. raniceps*) and a terrestrial (*L. elenae*) species registered only at the control site, may well be specialists of forested habitat.

The results of principal component and CCA showed that pond area, width of hedgerows, shore vegetation index and depth of ponds contributed significantly to variability of anuran diversity across agricultural ponds and the control site. The relationship between anuran diversity and pond area may be due to a habitat-island effect (MacArthur and Wilson 1967; Cook et al. 2002)

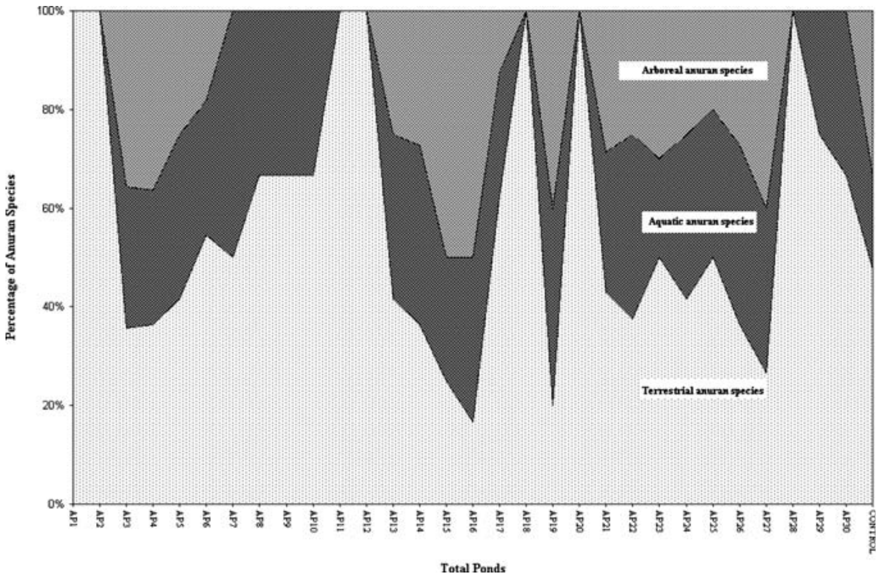


Figure 5. Percentages of ecological distribution of anurans across control and agricultural ponds. AP: agricultural ponds.

with the lowest diversity being predicted for the smallest patch (50 m^2). Several studies have investigated the effects of patch area on amphibians (e.g., Zimmerman and Bierregaard 1986; Hecnar and M'Closkey 1997; Peltzer et al. 2003) and they found it to be the most important variable in determining amphibian species diversity. Moreover, we observed increased anuran diversity with the hedgerow width. Comparable studies have shown that species diversity along riparian strips decreases with decreased width of field borders and increased disturbance of corridor and vegetation complexity of them (Szaro 1986; Maisonneuve and Rioux 2001; Marshall and Moonen 2002). Thus, the increase of anuran diversity with increasing depth could be because that deeper ponds may hold water long enough to support larval development in years when the shallower ponds dry before the larvae metarmophose. Indeed, shore vegetation in bodies of water are important for anurans, providing them structural heterogeneity, moisture, shelter, calling sites, refuge from pesticide contamination and places to attach their eggs (Stumpel and van der Voet 1998). It is well documented that cleared areas generally experienced greater temperature extremes at the surface and in the upper layers of the soil than areas with vegetation (Matlack 1997). This is consistent with the lower anuran diversity recorded at ponds with higher air temperatures.

The results of our study showed that the proportion of observed guilds among ponds was less than expected by chance. This could be due to the patchy distribution of amphibians (Bosch et al. 2004) and the complexity in vegetation structure (Maidonneuve and Rioux 2001). We found all guilds related to pond area. Large areas may hold a greater number of species and diversity than small pond areas. Indeed, we found that arboreal species such as *H. nana*, *H. pulchella*, *H. sanborni*, *H. raniceps*, *S. nasicus*, *S. acuminatus* and *S. squalirostris*, were found at large ponds with higher vegetation index values and presence of wider hedgerows. Species richness of terrestrial species (*B. arenarum*, *B. paracnemis*, *B. fernandezae*, *O. americanus*, *L. chaquensis*, *L. mystacinus*, *L. latinasus*, *L. gracilis*, *L. elenae*, and *E. bicolor*) was found to relate to large pond areas and more diverse shore vegetation. Finally, aquatic species (*L. limellus*, *P. albonotatus*, *P. biligonigerus*, *P. riograndensis*, *P. falcipes* and *L. ocellatus*) were related to pond area, shore vegetation index and depth. We conclude that arboreal guilds are more prone to local decline than the terrestrial and aquatic guilds and thus the guild proportionality changes in response to spatial heterogeneity (shore vegetation and hedgerows).

Evidently the factors that determine the presence of anuran species in a pond are part of a complex network of relationships and are strongly influenced by the local situation (Bishop et al. 1999). Anuran diversity across agricultural ponds of mid-western Entre Ríos Province can be affected by local habitat factors such as reduction in pond size and depth, shore vegetation richness, width of hedgerow and change in air temperatures. Moreover, we find that the ponds surrounded by soybean croplands vary in their capacity to support anuran species.

Implications for conservation

The result of our study provides managers with clues to preserve, create or restore anuran aquatic habitats in intensive agricultural areas where populations are low or declining. It appears that in order to maintain anuran diversity in agricultural landscapes, natural or artificial bodies of water must exist. Maintaining shore vegetation of ponds and hedgerow may increases number of species and diversity of anurans within agricultural landscapes. Knutson et al. (2004) also suggested that constructed farm ponds, properly managed, may help sustain amphibian populations in agricultural landscape and may represent important alternative breeding habitat.

Hedgerows are not only recognised as important corridors and habitats for a great diversity of species, but they also help reduce the impacts of agricultural practices on the water quality of pond by filtering pesticides, fertilizers, and they maintain quality of aquatic habitat by regularizing temperature (Maisonneuve and Rioux 2001). With respect to agricultural pesticides and fertilizers, different authors have suggested they are important factors in amphibian declines, malformation and survival (Bishop et al. 1999; Campana et al. 2003; Lajmanovich et al. 2003; Mann et al. 2003).

Effective management of amphibian in predominantly agricultural landscape requires and understanding of what factors influence anuran assemblages. Furthermore, conservation plans must account for the varied life history requirements and behaviours of different species. The reduction of area of suitable habitats is an obvious reason for decline, particularly in arboreal species, due to a more intensive use of available land.

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