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Herpetological Review, 2018, 49(4), 632–635.

Diversity of Anurans in Rice Fields under Organic and Conventional Management in Santa Fe Province, Argentina

Expansion and intensification of land use for agricultural activities during the last century have been the most important anthropogenic changes worldwide (Pascual and Perrings 2007). Therefore, it is important for biodiversity studies to include agroecosystems since these environments cover approximately 40% of the total soil surface area in the world (Tilman 1999). Rice (*Oryza sativa* L.) is the staple food of more than three billion people and is one of the most important grains for human nutrition (SOSBAI 2012). In Argentina, the rice-cultivated area has increased considerably, particularly in Santa Fe, Entre Ríos and Corrientes provinces (207,600 ha, 2016/2017 crop year), altogether accounting for approximately 90% of the national production (De Bernardi 2017). Rice fields are considered temporary wetlands characterized by rapid physical, chemical, and biological changes that in some cases, can contain greater biodiversity, especially amphibians (Bambaradeniya et al. 2004; Duré et al. 2008) compared to other agricultural crops (Attademo et al. 2005). In general, amphibians can be used as bioindicators of ecosystem quality, or at least of the niche they occupy (Attademo et al. 2007; 2014; Echegaray and Hernando 2003; Peltzer et al. 2006). These organisms have also been used as biological control agents in agricultural systems (Khatiwada et al. 2016).

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In recent years, organic rice production has increased notably in Argentina (Ministerio de Agroindustria 2018). This trend encourages the development of new alternatives that allow the expansion of cultivable lands in an environmentally friendly manner. Accordingly, agrochemicals for the control of weeds or harmful arthropods are not usually applied to these crops. In organic farming, some agroecological principles are ensured, such as biological and synergistic interactions among biodiversity components that promote key ecological processes and services (Krauss et al. 2011; Andersson et al. 2012; Maltchik et al. 2017). Here, we compare diversity and composition (richness, abundance) of anurans during a rice crop cycle between two (organic and conventional) management systems in Santa Fe province, Argentina.

The study area is located in Santa Fe Province, mid-eastern Argentina. The area of highest rice production is located between Romang (San Javier department) and Colonia San Joaquín (Garay department) to the north and south of the locality of San Javier respectively, encompassing a total cultivated area of 30,000 ha (López-Lanús and Marino 2010). Rice crops are planted in low deforested lands delimited by the Parana River to the east. The climate is hot and humid, with rainfall exceeding 1000 mm a year and an average annual temperature of 18° C (Burkart et al. 1999). Rice fields under two different management practices were selected: Conventional rice (CR; 30.6082°S, 59.9934°W), involving the use of pesticides in the production process, and organic rice (OR: 30.0867°S, 59.8885°W), with no application of pesticides or treatment with chemical or biological pesticides in the nearby area (approximately 3-km radius of the field). In general, CR management includes: application by airplane of herbicides such as glyphosate before sowing for the control of grasses; fertilization when plants are 7–10 days old; and application of organophosphate (chlorpyrifos 500cm^3/ha) and pyrethroid insecticides (lambda – cyhalothrin, 100 cm^3 in 20 L) for the control of arthropods at flowering (Attademo et al. 2015). Fungicides (bentazone and clomazone) are applied on a small scale and generally mixed with other pesticides.

Sampling Methods

Sampling was conducted from the beginning of sowing to the end of harvest (November 2017 – March 2018). The surveys were conducted during the rice-cropping period to coincide with the activity of anurans in this region. Samplings were made by two observers using visual encounters surveys (Crump and Scott 1994) at the selected sites from 1900 to 0100 every 15 days, totaling 20 sampling dates during the entire survey period at each site. At each site, four 100 m long transects were established, covering the different microhabitats present in these fields (ditches, patches, and rice crop; Duré et al. 2008). To avoid area and spatial-autocorrelation effects, an equal area was sampled in each rice field and transects were located at the same distance in each rice crop. The plots in each rice crop were randomly selected, and then the four transects were systematically established every 400 meters. Observers walked along the two transects and recorded direct observations through active searching. Additionally, calls were also recorded for individuals that were not observed along the transects (Duré et al. 2008).

Species richness (averaged over the four transects) and Shannon-Weaver diversity indices were compared between rice fields using individual-based rarefaction curves (± 95% CIs) calculated using the software EcoSim (Gotelli and Entsminger 2003). Rarefaction curves were based on the total number of individuals per species recorded in each rice-field. Non-overlapping Cls indicate a significant difference (Colwell et al. 2012). The Mann-Whitney non-parametric test was used to evaluate the differences in parameters between rice field transects (CR and OR) (Duré et al. 2008). Components of species nestedness and turnover of Sorensen index (Baselga 2010) were calculated using the *betapart* package (Baselga and Orme 2012) in R (R Core Team 2017) to assess the differences in species composition between rice fields (i.e., beta diversity). To compare the distributions of relative abundance between rice fields, rank/abundance curves were plotted (Magurran 2004) and five models were fitted (Broken stick, geometric series, general lognormal, Zipf, and Zipf-Mandelbrot; Wilson 1991). The best-fit model was selected using the Akaike information criterion (AIC). These analyses were conducted using the *vegan* package *(Oksanen 2011)* in R (R Core Team 2017).

Results

A total of 15 anuran species belonging to five families (Bufonidae, Leptodactylidae, Hylidae, Odontophrynidae, and Microhylidae) were recorded (Table 1). Diversity and species richness of anurans were higher in the organic than in the conventional rice fields (Fig. 1). Diversity values were significantly different between rice fields (Mann-Whitney, W= 155, P < 0.01) (Shannon-Weaver CR = 2.23 ± 0.06 and OR = 1.32 ± 0.02). Species richness was also significantly different (W= 135, P < 0.01) between rice fields (CR = 6.24 ± 0.39 and OR =13.01 ± 0.54). Differences in species composition between organic and conventional rice fields were related to species nestedness (β_{sne}= 0.30), whereas species turnover was not detected (β_{sim}= 0) because all species recorded in CR were also recorded in OR. The broken stick (AIC = 69.5) and the geometric series models (AIC = 63) were the ones with the best fit for the OR and CR fields, respectively (Delta AIC > 4 in both cases, Fig 2). This difference in the rank-abundance models between sites indicated a higher evenness in OR, with a shallower slope better adjusted by the broken stick model, than in CR, with a steeper slope better adjusted by the geometric series model.

Discussion

Of the 36 species of amphibians recorded in the study region (Peltzer and Lajmanovich 2007), 15 species were observed in our study plots. As in previous studies (Peltzer et al. 2006), our results showed that some anuran species (*L. latrans* and *L. lymellum*) were particularly abundant in the CR plots. Other species such as *Physalaemus albonotatus*, *P. santafecinus* and *Pseudopaludicola falcipes* were not found in CR plot. These species are common in open areas and are usually associated with grassland–herbaceous vegetation present in temporary watercourses, which are important during the reproductive season (Peltzer et al. 2006). However, those species, as well as arboreal species such as *Scinax nasicus*, were present in the OR plot where no herbicides were applied, allowing the aquatic vegetation to develop. This result agrees with the geometric series model, which can be applied to species-poor environments with high dominance such as polluted environments (Magurran 2004; Matthews and Whittaker 2015). Accordingly, Bishop et al. (1999) reported that highly altered systems, such as crops under conventional management, are characterized by the presence of anuran communities dominated by a few taxa. The"broken stick" model on the other hand, is consistent with higher evenness (i.e., a greater similarity in abundance among species; Magurran 2004), which agrees with the results obtained in the OR field.

The difference in amphibian diversity between the two environments may be due to a number of variables that can have an effect on amphibian assemblages in agricultural systems (Weyrauch and Grubb 2004; Maes et al. 2008). These rice fields are subjected to different agricultural management practices such as the degree of conservation of vegetation at the edge of plots, use of crop rotation, agrochemicals, and their mode of application (Attademo et al. 2005). These practices can have positive or negative effects on some amphibian species (Vos and Stumpel 1995). In agroecosystems under organic agriculture, biodiversity can be increased through reduced nutrient leaching (Drinkwater et al. 1995), reduced soil erosion (Reganold et al. 1987), and lower levels of pesticides in aquatic systems (Mäder et al. 2002) compared to conventional fields. This increase in species richness may be important at the ecosystem level, because this parameter is usually positively associated with functional diversity and therefore, with the provision of ecosystem services through biodiversity (Flynn et al. 2009). However, because the

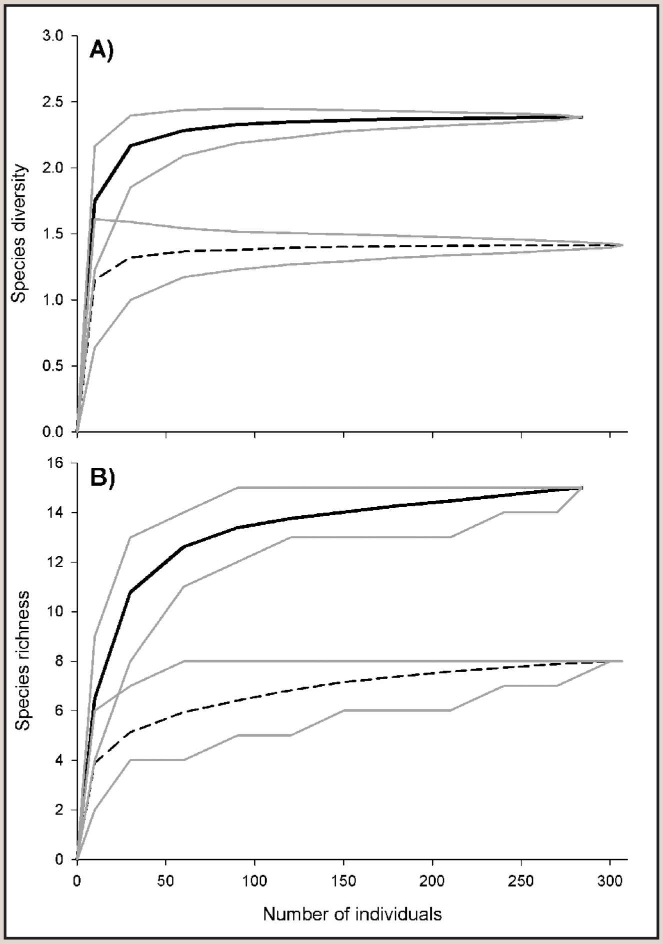

FIG. 1. Individuals-based rarefaction curves of species diversity (A) and richness (B) of organic (continuous line) and conventional (discontinuous line) rice fields. 95% intervals of confidence (grey lines) are shown.

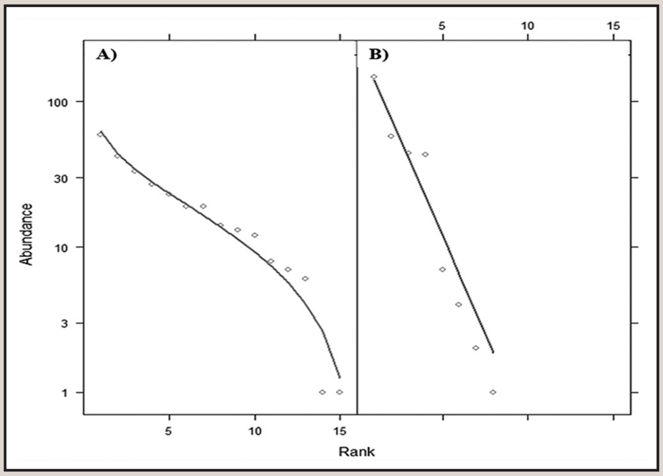

FIG. 2. Rank-abundance curves of anuran assemblages in organic (solid circles) and conventional (empty circles) rice fields. Best fit models for organic (broken stick model, continuous line) and conventional (geometric series model, discontinuous line) rice fields are shown.

TABLE 1. Total composition of individuals (N) and frequency (%) of amphibian species in an organic rice field (OR) and a conventional rice field (CR) in Santa Fe province, Argentina.

	OR		CR	
Amphibian species	N	%	N	%
BUFONIDAE				
Rhinella fernandezae	12	4.22	4	1.30
R. schneideri	13	4.55	2	0.65
LEPTODACTILYDAE				
Leptodactylus latrans	14	4.92	148	48.21
L. chaquensis	59	20.77	43	14.01
L. latinasus	1	0.35		—
L. gracilis				
Physalaemus santafecinus	19	6.69	—	—
P. albonotatus	7	2.46	—	—
Pseudopaludicola falcipes	23	8.09	—	—
ODONTOPHRYNIDAE				
Odontophrynus americanus	1	0.35	—	—
HYLIDAE				
Dendropsophus aff. nanus	19	6.69	44	14.33
Scinax acuminatus	27	9.51	1	0.32
S. nasicus	6	2.11	—	—
Pseudis paradoxa	33	11.62	7	2.28
Lysapsus limellum	42	14.79	58	18.90
MICROHYLIDAE				
Elachistocleis bicolor	8	9.52	—	—
Total	284		307	

relationship between species richness and functional diversity is not necessarily positive (Mayfield et al. 2010), our results should be complemented with the assessment of functional diversity.

In conclusion, our study provides preliminary data that show significant differences in amphibian diversity between conventional and organic rice fields. Because our sampling sites were not independently replicated (N = 1), more studies are needed to fully assess the impact of different crop management practices on amphibian diversity. However, our preliminary results highlight the potential mitigative effects of organic farming on biodiversity, which is important because modern agriculture in general has obtained high economic returns at the expense of biodiversity loss (Peltzer et al. 2006), with cascading negative biological and ecological ramifications (Attademo et al. 2014; 2015).

Acknowledgments.—We thank farmers for permission to work in their fields (Cooperativa “ El Progreso” and Cooperativa Arrocera “Villa Elisa”). This study was supported by Curso de Acción para la Investigación y Desarrollo (Programa de I+D Orientado a Problemas Sociales y Productivos, UNL: Importancia de los bordes de campo de arroz orgánico en el rol de los vertebrados en el control biológico de plagas). We thank Jorgelina Brasca for editing the manuscript.

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