SHORT NOTES

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THE EFFECTS OF HABITAT FRAGMENTATION ON AMPHIBIAN SPECIES RICHNESS IN THE FLOODPLAIN OF THE MIDDLE PARANA RIVER, ARGENTINA

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The Middle Paraná river includes a complex system of islands interspersed with riparian woodland and gallery forest, making this an important area for the herpetofauna of Argentina (Bridarolli & di Tada, 1994). However, the Middle Paraná river floodplain is being increasingly fragmented by human activity to the point where existing amphibian populations may be dependent on marginal or altered wetlands for their survival (Peltzer & Lajmanovich, 2001). In this context, some authors have emphasized that amphibians may be vulnerable to habitat fragmentation (e.g. Blaustein *et al.*, 1994; Lavilla, 2001) because of their complex life history patterns and population dynamics (Delis *et al.*, 1996). Moreover, the dispersal patterns of amphibians are likely to be influenced by habitat quality and the distance between suitable patches of breeding habitats (Dodd & Cade, 1998).

In this study, we compare anuran species richness between ponds located in remnants of riparian woodlands representing a range of habitat variables and patch parameters in the Middle Parana river floodplain. The study area is situated in the western zone of the Entre Ríos Province (31° 44'S – 60° 31'W). Vegetation communities are dominated by subtropical elements in contrast to the surrounding temperate spiny vegetation (Burkart *et al.*, 1999). Climatically, this area has an average annual rainfall below 1000 mm and a mean annual temperature of 18°C.

Landsat images and serial aerial photographs (first order to fifth order at a scale of 1:50 000, Brigada Aérea Argentina at Paraná City of Entre Ríos Province) were used to select eight ponds: one located within a pristine riparian woodland (PSM Natural Protected Reserve "Parque General San Martín" - 6940 m^2) and seven located in suburban riparian woodlands that differed in degrees of disturbance (VU: Villa Urquiza 1500 m^2, BG: Bajada Grande - 1300 m^2, TH: Tomphson - 10 m^2, PC: Parque Costero - 400 m^2, PU: Parque Urquiza - 4741 m^2, AN: Acceso Norte - 2100 m^2, REG: Regionales - 375 m^2).

Field survey. We surveyed the eight ponds for anurans between 1 January 1999 and 31 March 2000. Each month we conducted four or five field trips of about 1-6 hr duration, depending on the pond size and the time spent on collection and identification. We conducted nocturnal site searches to sample adult anurans, beginning shortly after sunset (1900 hr) and extending until midnight. This technique is a combination of the visual encounter surveys of Crump & Scott (1994) and audio strip transects of Zimmerman (1994). A fine-meshed net was used to take samples at different times of the day, but always in daylight. The captured adults and larvae were identified, photographed and then released. Unidentifiable specimens (larval or adult) were fixed in 10% formalin and deposited in the Natural Sciences Museum "Florentino Ameghino" of Santa Fe Province (Argentina) and in the Instituto Nacional de Limnología for later identification.

We recorded nine habitat variables: pH (with Lovibond), air temperature (with a standard thermometer) and maximum depth (with meter). Turbidity was estimated by eye on an ordinal scale of 0-5 (Marnell, 1998), where 0 was crystal clear and 5 was so turbid that light would not penetrate a 5 cm sample jar. Estación Tecnológica Agropecuaria-INTA (located in Paraná City, Entre Ríos Province) provided data on relative humidity and the total monthly volume of precipitation. The noise level was estimated on an ordinal scale, where 0 was an absence of human-generated noise and 3 was a high level of noise (a site near a road, beach or urban development). Aquatic macrophytes and shore vegetation were identified and the vegetation richness for each site was gauged on a qualitative scale ranging from 1 to 5 (Coneza Fernandez Vitora, 1997), where 1 was a monospecific vegetation and 5 was very diverse vegetation. The level of disturbance to the aquatic and surrounding terrestrial habitats was gauged on an arbitrary scale of 0-5 (Pavignano, 1988), where 0 was a natural site without alterations, and 5 was a site completely altered by floods, humans (roads, agriculture, deforestation, excavation, and intentional fire) or farm animals. Moreover, we determined three patch parameters in accordance with the theory of MacArthur & Wilson (1967): pond area (m^2), distance (in km) to the pristine riparian woodland, and time since the remnant was isolated (years). We used two levels of distance (1-20 km and >20 km) and two levels of isolation (1-10 years and >11 years). Serial aerial photographs (scales 1:100 000; 1:50 000, and 1:25 000) provided by Brigada Aérea Argentina at Paraná City of Entre Ríos Province were used to estimate time since isolation.

Data analysis. We calculated the similarity between survey sites in terms of the composition of anuran assemblages using the Jaccard similarity measure (Magurran, 1987). The similarity values were used to

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construct a site by site similarity matrix for the eight survey sites. We clustered the sites on the similarity of their anuran assemblages using the Unweighted Pair Group Method using Arithmetic Averages (UPGMA) method (Sneath & Sokal, 1973).

We calculated Bravais-Pearson correlation coefficients (Sokal & Rohlf, 1979) to relate species richness to the habitat variables at each site. We also used a multiple regression to relate species richness to pond area, time since isolation, and distance to the pristine riparian woodland. All analyses were performed using the statistical programme Statgraphic version 1.11 (1994).

A total of 20 anuran species belonging to five families was detected in ponds located in remnants of riparian woodland of the Middle Parana river floodplain (Table 1). Three species (*Pseudopaludicola falcipes, Physalaemus riograndensis* and *Physalaemus albonotatus*) were exclusively recorded in the pond within the pristine riparian woodland. Anuran species found on both disturbed and pristine sites were *Bufo fernandezae, B. arenarum, B. paracnemis, Leptodactylus ocellatus, L. chaquensis, L. mystacinus, L. latinasus, L. gracilis, L. elenae, Physalaemus biligonigerus, Hyla nana, H. pulchella, Scinax nasicus, S. squalirostris* and *Elachistocleis bicolor*. The most common species observed in both habitats was *B. arenarum*, recorded in 87.5% of the total ponds sampled, following by *L. latinasus* (75%).

Cluster analysis of the eight surveyed sites based on the similarity of the composition of their anuran assemblages produced two groups (Fig. 1). PSM, PU and AN had a close association, while VU and REG formed another distinct group. PC, BG and TH had a distant association with the other two groups.

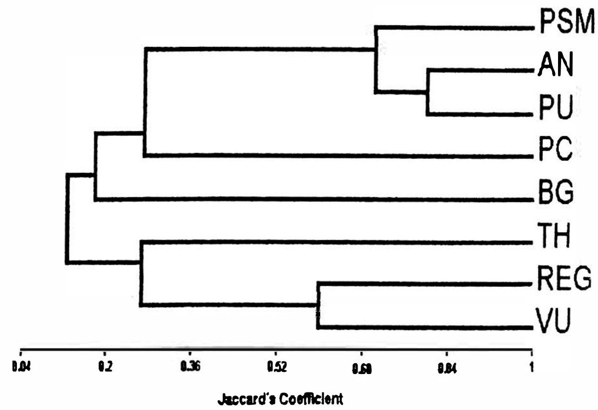

FIG. 1. Cluster analysis of the eight survey sites, examining the similarity of their anuran richness.

We found six of the nine habitat variables to be significantly correlated with anuran species richness at the study sites: air temperature (r=0.83, df=7, P<0.01), relative humidity (r=0.75, df=7, P<0.01), the logarithm of the water turbidity (r=-0.80, df=7, P<0.01), vegetal richness (r=0.73, df=7, P<0,05), levels of disturbance (r=-0.92, df=7, P<0.01), and noise presence (r= -0.73, df=7, P<0.05). No relationships were found between species richness and water depth, pH or the logarithm of total monthly volume of precipitation.

The combination of pond area, time since isolation and distance to pristine woodland provided the best fit to the variation in species richness (R^2=0.98, F=79.7, df=7, P<0.001). t-tests for the individual explanatory

TABLE 1. Anuran species richness of ponds in riparian woodland of the Middle Parana River. VU, Villa Urquiza; BG, Bajada Grande; TH, Tomphson; PC, Parque Costero; PU, Parque Urquiza; AN, Acceso Norte; REG, Regionales; and PSM, Parque General San Martín. (+) indicates that the species was present and (-) that it was not detected.

Species	Disturbed							Pristine
	VU	BG	TH	PC	PU	AN	REG	PSM
Bufo fernandezae	-	-	-	-	+	+	-	+
Bufo arenarum	+	+	+	-	+	+	+	+
Bufo paracnemis	+	-	-	-	-	-	-	+
Leptodactylus ocellatus	+	-	-	-	+	+	+	+
Leptodactylus chaquensis	-	-	-	-	+	-	-	+
Leptodactylus mystacinus	+	-	-	-	+	+	+	+
Leptodactylus latinasus	+	-	-	+	+	+	+	+
Leptodactylus gracilis	-	-	-	-	-	+	-	+
Leptodactylus elenae	-	-	-	+	+	+	-	+
Physalaemus biligonigerus	-	-	-	+	+	+	-	+
Physalaemus riograndensis	-	-	-	-	-	-	-	+
Physalaemus albonotatus	-	-	-	-	-	-	-	+
Pseudopaludicola falcipes	-	-	-	-	-	-	-	+
Lysapsus limellus	-	+	-	-	-	-	-	-
Hyla nana	-	+	-	+	+	+	-	+
Hyla pulchella	-	-	-	-	+	+	-	+
Scinax nasicus	-	+	-	-	+	+	-	+
Scinax acuminatus	-	-	-	-	+	-	-	-
Scinax squalirostris	-	-	-	-	+	+	-	+
Elachistocleis bicolor	-	-	-	-	+	+	-	+
Species Richness	5	4	1	4	14	13	4	18

variables in the combined model indicated that both pond area and time since isolation contributed significantly to the regression (t_{area}=3.99, df=7, P<0.05; t_{time}=4.38, df=7, P<0.01).

We found anuran richness to be positively related to air temperature, relative humidity and vegetation richness but negatively related to water turbidity, level of noise, and disturbance. The relationship between temperature, relative humidity, and anuran richness is consistent with previous observations in tropical habitats in the Brazilian Amazon (Tocher *et al.*, 1997). In this context, the reproductive activity of anurans in tropical and subtropical areas depends on the combination of temperature and rainfall (Duellman & Trueb, 1986). However, the calling activity and presence of the species in ponds located in remnants of riparian woodland were not correlated with the total monthly volume of precipitation. This may be because South America experienced a severe drought throughout the period of the study associated with what many consider the strongest El Niño-Southern Oscillation (post-ENSO) event of the last century (Hammond & ter Steege, 1998; McPhaden, 1999). The scarce records of the common frogs *Scinax acuminatus* and *Lysapsus limellus* and the complete absence of *Hyla raniceps,* a species previously recorded for this area (pers. obs.), may be due to the dry weather and a consequent lack of suitable breeding sites.

Anuran populations may be concentrated in areas of more appropriate habitat surrounding urban development, thereby increasing relative richness in these areas. In our study, the riparian woodlands of the Middle Paraná river floodplain with no – or only low levels of – disturbance were found to be even more significant as refuges from urban and agricultural development. Roads, deforestation, excavation, agricultural activities and livestock grazing are increasing the isolation of remnants of riparian woodland and contributing to habitat fragmentation. The potential effects of agricultural pesticides and fertilizers on amphibian growth, development and suitable breeding sites should also be considered (Tyler & Williams, 1996; Bishop *et al.*, 1999). *Scinax nasicus*, *Bufo arenarum* and *Physalaemus biligonigerus* larvae have been found to be sensitive to cypermethrin and paraquat (Lajmanovich *et al.*, 1998; Izaguirre *et al.*, 2000).

We found a significant correlation between anuran richness and plant species richness at the ponds surveyed. Aquatic vegetation and shore vegetation in the riparian areas are important for anurans, providing them structural heterogeneity, moisture, shelter, calling sites, and places to attach their eggs (Stumpel & van der Voet, 1998).

Two of the patch measurements, pond area and time since isolation, contributed significantly to the regression model of anuran richness. The positive relationship between anuran richness and pond area may be due to a habitat-island effect (MacArthur & Wilson, 1967), with the lowest richness being predicted for the smallest patch (10 m^2). Some studies have investigated the effects of patch area on amphibians (e.g. Zimmerman & Bierregard, 1986; Hecnar & M'Closkey, 1997) and found it to be the most important variable in determining amphibian species richness. Although we have not considered the anuran richness of the matrix, it is possible that anurans may disperse through the riparian corridors, transitional lands adjacent to streams, oxbows and gallery forest. This may explain the absence of a statistically significant relationship between anuran richness and distance to pristine woodland.

Our results indicate that altered remnants of riparian woodland in the Middle Parana river floodplain with low temperature and relative humidity, monospecific vegetation, turbid water and proximity to urban development or roads have few anuran species. Although these results are preliminary, it is evident that habitat modification and fragmentation of the riparian woodland of the Middle Parana river by human activities have resulted in a decrease in anuran richness. On the other hand, the limited infonnation available on the biology and dispersal capability of the amphibians of the study area (Lajmanovich, 1997; 2000; Peltzer & Lajmanovich, 1999; 2000; 2002) makes it difficult to asses how they might be impacted by habitat alteration.

We conclude that the likelihood of maintaining biological diversity in the riparian woodlands of the Middle Parana river floodplain will be increased by protection of the relatively scarce remnants, and minimization of further fragmentation and disturbance of the landscape.

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REFERENCES

Bishop, C. A., Mahony, N. A., Struger, J., Ng., P. & Pettit, K. E. (1999). Anuran development, density and diversity in relation to agricultural activities in the Holland River watershed, Ontario, Canada (1990-1992). *Environ. Monit. Assess.* **57,** 21-43.

Blaustein, A. R., Wake, D. B. & Sousa, W. P. (1994). Amphibian declines: judging stability, persistance, and susceptibility of populations to local and global extinctions. *Conserv. Biol.* **8,** 60-71.

Bridarolli, M. E. & di Tada, I. (1994). Biogeografía de los anfibios anuros de la regi6n central de la República Argentina. *Cuadernos de Herpetologia.* **8,** 63-82.

Burkart, R., Bárbaro, N. O., Sanchez, R. O. & Gómez D. (1999). *Eco-Regiones de la Argentina.* Administración de Parques Nacionales (Ed.), Buenos Aires.

Coneza Fernández-Vítora, V. (1997). *Guia metodológica para la evaluación del impacto ambiental.* Mundi Prensa, Madrid.

Crump, M. L. & Scott, N. J. (1994). Visual encounter surveys. In *Measuring and Monitoring Biological*

Diversity - Standard Methods for Amphibians, 84-91. Heyer, W. R., Donelly, M. A., McDiarmid, R. W., Hayek, L. C. and Foster, M. S. (Eds.). Washington & London: Smithsonian Institution Press.

Delis, P. R., Mushinsky, H. R. & McCoy, E. D. (1996). Decline of some west-central Florida anuran populations in response to habitat degradation. *Biodiv. Conserv.* **5,** 1579-1595.

Dodd, K. D. & Cade, B. S. (1998). Movement patterns and conservation of amphibians breeding in small, temporary wetland. *Conserv. Biol.* **12,** 332-339.

Duellman, W. E. & Trueb, L. (1986). *Biology of Amphibians*. McGraw-Hill Book Company, New York.

Hammond, D. S. & ter Stegge, H. (1998). Propensity for fire in Guianan rainforests. *Conserv. Biol.* **12,** 944-947.

Hecnar, S. J. & M'Closkey, R. T. (1997). Patterns of nestedness and species association in a pond dwelling amphibian fauna. *Oikos* **80,** 371-381.

Izaguirre, F, Lajmanovich, R. C., Peltzer, P. M., Peralta-Soler, A. & Casco, V. (2000). Cypermethrin-induced apoptosis in the telencephalon of *Physalaemus biligonigerus* tadpoles (Anura: Leptodactylidae). *Bull. Environ. Cont. Toxicol.* **65,** 501-507.

Lajmanovich, R. C. (1997). Alimentación de larvas de anuros en ambientes temporales del sistema del río Paraná, Argentina. *Doñana Acta Vertebrata* **24,** 191-202.

Lajmanovich, R. C. (2000). Interpretación ecológica de una comunidad larvaria de anfibios anuros. *Interciencia* **25,** 71-79.

Lajmanovich, R. C., Izaguirre, M. F. & Casco, V. H. (1998). Paraquat tolerance and alteration of internal gills structures of *Scinax nasicus* tadpoles (Anura: Hylidae). *Archiv. Environ. Cont., Toxicol.* **34,** 364-369.

Lavilla, E. O. (2001). Amenazas, declinaciones poblacionales y extinciones en anfibios argentinos. *Cuadernos de Herpetologia.* **15,** 59-82.

MacArthur, R. H. & Wilson, E. O. (1967). *The Theory of Island Biogeography*. New Jersey: Princenton Univ. Press.

Magurran, A. E. (1987). *Ecological Diversity and its Measurements*. New Jersey: Princeton Univ. Press.

Marnell, F. (1998). Discriminant analysis of the terrestrial and aquatic habitat determinants of the smooth newt (*Triturus vulgaris*) and the common frog (*Rana temporaria*) in Ireland. *J. Zool. London* **244,** 1-6.

McPhaden, M. J. (1999). The child prodigy of 1997-98. *Nature* **398,** 559-562.

Pavignano, I. (1988). A multivariate analysis of habitat determinants for *Triturus vulgaris* and *T. carnifex* in northwestern Italy. *Alytes* **7,** 265-272.

Peltzer, P. M. & Lajmanovich, R. C. (1999). Análisis trófico en dos poblaciones de *Scinax nasicus* (Cope, 1862) (Anura: Hylidae), Argentina. *Alytes* **16,** 84-96.

Peltzer, P. M. & Lajmanovich, R. C. (2000). Dieta de *Hyla nana* (Anura: Hylidae) en charcas temporarias de la llanura aluvial del río Paraná, Argentina. *Boletin de la Asociación Herpetológica Española* **11,** 71-73.

Peltzer, P. M. & Lajmanovich, R. C. (2001). Habitat Fragmentation and Amphibian Species Richness in Riparian Areas of the Parana River, Argentina. *Froglog* **46,** 5.

Peltzer, P. M. & Lajmanovich, R. C. (2002). Preliminary studies of food habits of *Lysapsus limellus* (Anura, Pseudidae) in lentic environments of Paraná River, Argentina. *Bulletin de la Société Herpétologique de France* **101,** 53-58.

Sneath, P. H. & Sokal, R. R. (1973). *Numerical Taxonomy*. W. H. Freeman & Co. San Francisco.

Sokal, R. R. & Rohlf, F. J. (1979). *Biometría*. Blumé, Madrid.

Statgraphics® (1994). *Plus* For Windows. Versión 1.11. Licensed to: INALI. Serial Number: 38076603. Copyright© by Statistical Graphics Corp.

Stumpel, A. H. P. & van der Voet, H. (1998). Characterizing the suitable of new ponds for amphibians. *Amphibia-Reptilia*, **19,** 125-142.

Tocher, M. D., Gascon, C. & Zimmermann, B. (1997). Fragmentation effects on a central Amazonian frog community: A ten-year study. In *Tropical Forest Remnants: Ecology, Management and Conservation of Fragmented Communities*, 124-137. Laurence, W. F. and Bierregard, R. O. (Eds.). Chicago & London: University of Chicago Press.

Tyler, M. & Williams, C. (1996). Mass frog mortality at two localities in South Australia. *Trans. R. Soc. South Australia* **120,** 179.

Zimmerman, B. L. (1994). Audio strip transects. In *Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians*, 92-97. Heyer, W. *et al.* (Eds.). Washington & London: Smithsonian Institution Press.

Zimmerman, B. & Bierregaard, R. O. (1986). Relevance of the equilibrium theory of island biogeography and species-area relations to conservation with a case from Amazonia. *J. Biogeography* **13,** 133-143.

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