ECOREGIONAL INFLUENCES ON THE AMPHIBIAN ASSEMBLAGE OF RESERVA NATURAL LAGUNA BLANCA, DEPARTAMENTO SAN PEDRO, PARAGUAY

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ABSTRACT

Reserva Natural Laguna Blanca (RNLB) has recently been proposed as Paraguay's first Important Area for the Conservation of Reptiles and Amphibians. The reserve lies within the Atlantic Forest ecoregion of Paraguay as currently understood. A similarity analysis was performed to assess which of the ecoregions most influence upon the community of amphibians. It was concluded that the amphibian fauna of the reserve is most strongly influenced by the Cerrado ecoregion and it should thus be considered a southern fragment of this ecosystem. The results suggest that the inventory of the amphibian fauna of the Paraguayan Cerrado is not yet complete. This study highlights the utility of local scale biogeographical analysis as a conservation tool for conservation planners, land managers and biologists for designating national priority areas for conservation and identifying potential areas of endemism in under–sampled regions.

Keywords:
Atlantic Forest, Cerrado, Humid Chaco.

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INFLUENCIAS DE LAS ECORREGIONES SOBRE LA COMUNIDAD DE ANFIBIOS DE RESERVA NATURAL LAGUNA BLANCA, DEPARTAMENTO DE SAN PEDRO, PARAGUAY

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RESUMEN

La Reserva Natural Laguna Blanca (RNLB) fue propuesta recientemente como la primer Área Importante para la Conservación de Reptiles y Anfibios en Paraguay. La reserva está ubicada actualmente en la región designada como cobertura del Bosque Atlántico. Se realizó un análisis de similitud para determinar cuáles de las ecorregiones Paraguayas tiene más influencia sobre la comunidad de anfibios. Se concluye que la biodiversidad de anfibios está influida principalmente por el Cerrado, y la reserva debe ser considerada como un fragmento sureño de este ecosistema. Los resultados sugieren que el inventario de anfibios en el Cerrado paraguayo todavía es incompleto. El estudio demuestra la utilidad de análisis biogeográfico a escala local como una herramienta para conservacionistas, administradores de tierras y biólogos para designar áreas de prioridad nacional para la conservación, e identificar áreas de endemismo potencial en regiones sub-muestreadas.

Palabras clave:
Bosque Atlántico, Cerrado, Chaco Húmedo.

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INTRODUCTION

Ecological biogeography is the study of the distribution of species in relation to the ecosystems in which they live (Huggett 1998), but while global or regional analyses of fauna are common, those that concentrate on the ecoregional influences on fauna at the local scale are less so. The rarity of such analyses in the Neotropics is perhaps due to the fact that they are thought to require a relatively complete local inventory of species present and that such data is infrequently available, but their importance in identifying fine scale patterns of distribution, particularly in areas of transition between habitats, may be being overlooked.

The biogeographical regions of Paraguay have been repeatedly redefined (Keel *et al.*, 1993; Dinerstein *et al.*, 1995; Hayes, 1995; Morrone, 2001; Guyra Paraguay, 2005). The most commonly accepted opinion today involves an amalgamation of these ideas and the country is now generally considered to stand at the interface of seven major ecoregions: Dry Chaco, Humid Chaco, Pantanal, Paraguay Central, Cerrado, Atlantic Forest and Mesopotamian Grasslands/Pampas (Figure 1).

The completion of a five year herpetological inventory at Reserva Natural Laguna Blanca (RNLB), Departamento San Pedro, Paraguay (Smith *et al.* 2016), located in a habitat mosaic at the southern tip of the Cerrado, western extension of the Atlantic Forest and eastern reaches of the Humid Chaco allowed such an analysis to be carried out. Amphibians make up 34 % of the total herpetofauna (94 species) recorded at the reserve (Smith *et al.*, 2016). I examined the biogeographical influences on the local amphibian fauna of the RNLB based on our current knowledge of amphibian distribution.

MATERIALS AND METHODS

STUDY SITE

RNLB (S 23º 48´, W 56º 17´) is an 804 ha private reserve in northeastern Paraguay consisting of over 400 hectares of near pristine Cerrado, a patch of degraded Atlantic Forest and areas of transitional semi–deciduous, semi–humid gallery forest. The four main Cerrado ecotopes are present at RNLB and grow on a predominately sandy substrate (Eiten, 1972, 1978). The reserve is based around an eponymously–named freshwater lake of 157 ha which is possibly the only geologically true lake in Paraguay (Guyra Paraguay, 2008). The lake is low–nutrient with a sandy bed, and bordered by tall, wet grassy vegetation, sandy beaches and gallery forest. The lake is formed by a natural spring and feeds local freshwater systems in the surrounding area via a series of streams which, in the catchment area of the reserve form inundated marshy formations in an area transitional with habitat typical of the Humid Chaco. Temporary pools are formed in bushy depressions at the edge of humid forest after periods of heavy rain.

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	CER	AF	DCH	HCH	PAN	PAM	CAA
Amphibia							
Siphonopidae (1)							
Siphonops paulensis (e)	x	x					x
Hylidae (12)							
Dendropsophus jimi (b)	x						
Dendropsophus minutus (f)	x	x		x		x	
Dendropsophus nanus (a)	x	x	x	x	x	x	x
Hypsiboas albopunctatus (e)	x	x				x	
Hypisboas punctatus (a)	x	x	x	x	x		
Hypsiboas raniceps (a)	x	x	x	x	x	x	x
Scinax fuscomarginatus (f)	x	x		x		x	
Scinax fuscovarius (a)	x	x	x	x		x	
Scinax nasicus (a)	x	x	x	x	x	x	
Scinax squalirostris (d)		x		x		x	
Trachycephalus typhonius (a)	x	x	x	x	x		x
Phyllomedusa azurea (a) (d)		x	x	x	x	x	
Leptodactylidae (8)							
Adenomera diptyx (d)		x		x	x		
Leptodactylus chaquensis (a)	x	x	x	x	x		
Leptdactylus elenae (a)	x	x	x	x	x		
Leptodactylus fuscus (a)	x	x	x	x	x	x	x
Leptodactylus labyrinthicus (f)	x	x		x			
Leptodactylus mystacinus (f)	x	x	x	x			
Leptodactylus latrans (a)	x	x	x	x	x	x	x
Leptodactylus podicipinus (a)	x	x	x	x	x		x
Cycloramphidae (1)							
Odontophrynus cf. americanus (f)	x	x		x		x	
Leiuperidae (5)							
Eupemphix nattereri (f)	x	x		x	x		
Physalaemus albonotatus (a)	x	x	x	x	x	x	
Physalaemus centralis (e)	x	x					x
Physalaemus cuvieri (a)	x	x		x		x	x
Physalaemus marmoratus (b)	x						
Bufonidae (2)							
Rhinella schneideri (a)	x	x	x	x	x		
Rhinella scitula (b)	x						

Table 1. (Continued on the next page.)

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Table 1. (Continued from the previous page.)

Microhylidae (3)							
Chiasmocleis albopunctata(e)	x	x			x		
Elachistocleis bicolor (a)	x	x	x	x	x	x	
Elachistocleis matogrosso(b) (c)	x						
TOTALS	29	28	16	24	17	15	9
PERCENTAGE OVERLAP	90,6	87,5	50	75	53,1	46,9	28,1

Table 1. Composition of the amphibian assemblage at Reserva Natural Laguna Blanca, Departamento San Pedro, Paraguay, compared to other regional Neotropical ecoregions.

Biogeographic distribution categories: (a) generalist species with extensive distributions (present in five or more ecoregions), (b) species shared exclusively with Cerrado ecoregion, (c) species endemic to the study area in Paraguay, (d) species shared with Atlantic Forest and Humid Chaco ecoregions but not with Cerrado ecoregion, (e) species shared with Atlantic Forest and Cerrado ecoregions but not with Humid Chaco ecoregion, (f) species shared with Cerrado, Atlantic Forest and Humid Chaco ecoregions. CER Cerrado, AF: Atlantic Forest, DCH: Dry Chaco, HCH: Dry Chaco, PAN: Pantanal, PAM: Pampas, CAA: Caatinga. See text for details.

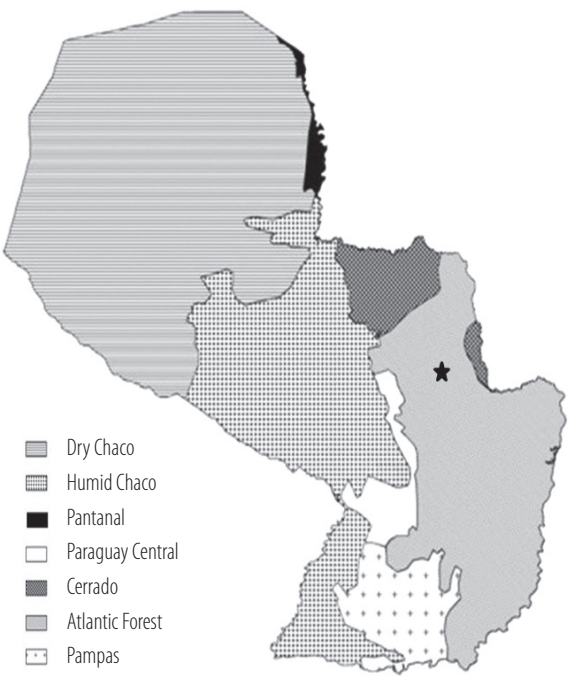

Figure 1. Distribution of Paraguayan ecoregions as commonly understood today.

In this work the poorly–defined Paraguay Central is included within the Humid Chaco (map produced by P. Cacciali). Star represents the location of Reserva Natural Laguna Blanca.

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ANALYSIS

Following a methodology used by Werneck & Colli (2006), I compared the amphibian list of RNLB (Smith *et al*., 2016) with those of Neotropical ecoregions suspected to have an influence on the local fauna by compiling species lists from the literature and our own data for Paraguay. Amphibian source lists for the different ecoregions were based on: Atlantic Forest (Brusquetti & Lavilla, 2006; Lavilla & Brusquetti, 2010; Nuñez, 2012), Cerrado (Colli *et al.*, 2002; Brusquetti & Lavilla, 2006; Lavilla & Brusquetti, 2010; Caramaschi, 2010), Caatinga (Rodrigues, 2003), Dry Chaco (Brusquetti & Lavilla, 2006; Lavilla & Brusquetti, 2010), Humid Chaco (Brusquetti & Lavilla, 2006, Lavilla & Brusquetti, 2010), Mesopotamian Grasslands/Pampas (Nuñez, 2012), Pantanal (Brusquetti & Lavilla, 2006). The taxonomic arrangement follows Weiler *et al*. (2013).

To evaluate the contribution of neighbouring ecoregions to the amphibian fauna of RNLB, species were grouped into the following seven biogeographic patterns of occurrence: (a) generalist species with extensive distributions (present in five or more ecoregions), (b) species shared exclusively with the Cerrado ecoregion (i.e. Cerrado endemic), (c) species endemic to the study area in Paraguay, (d) species shared with Atlantic Forest and Humid Chaco but not with the Cerrado ecoregion, (e) species shared with Atlantic Forest and Cerrado ecoregions but not with the Humid Chaco ecoregion, (f) species shared with Cerrado, Atlantic Forest and Humid Chaco ecoregions, but not a generalist species (g) species shared exclusively with Mesopotamian Grassland/Pampas, Pantanal, Dry Chaco or Caatinga. For the purpose of this work, Paraguay Central, a poorly defined ecoregion that is essentially an area of transition between Humid Chaco and Atlantic Forest, was considered to form part of the Humid Chaco following Guyra Paraguay (2005) and was not included in the analysis.

Percentage of amphibian overlap between RNLB and the different ecoregions was calculated as the number of species documented in a given ecoregion across the species range that were also recorded at RNLB / 32 (the total number of species recorded at RNLB). Total influence of an ecoregion was calculated as the number of species documented in a given ecoregion across the species Paraguayan range (or global range in the case of Caatinga) and also recorded at RNLB / number of species recorded in Paraguay known to occur in the same ecoregion.

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RESULTS

SPECIES DIVERSITY

a) *Generalist species.* – Sixteen of the 32 species of amphibians (50% of total) have generalized distributions among the ecoregions considered, being found in at least five of them. Generalist species were distributed amongst all families except Siphonopidae and Cycloramphidae and were most prevalent in the Leptodactylidae (62, 5 % of species) and Hylidae (58,3 % of species).

b) *Species shared exclusively with the Cerrado ecoregion.* – Four amphibians *Dendropsophus jimi, Physalaemus marmoratus, Rhinella scitula* and *Elachistocleis matogrosso* (12,5 % of total) recorded at RNLB are shared exclusively with the Cerrado ecoregion and may be considered endemic to that habitat. The faunal overlap with that reported for the Cerrado ecoregion in Paraguay is near complete 90,6 %. The total influence of the Cerrado is 107,4 %, a number reflecting the lack of sampling in the Paraguayan Cerrado.

c) *Species endemic to Reserva Natural Laguna Blanca in Paraguay. – Elachistocleis matogrosso* is the only species recorded in the reserve that is not known to occur at any other Paraguayan locality. Species limits in this genus are however in a state of frequent redefinition and this species may have been overlooked in Paraguay and hence prove to be more widespread than is currently known (Caramaschi, 2010; Brouard *et al.*, 2015).

d) *Species shared with Atlantic Forest and Humid Chaco but not with the Cerrado ecoregion.* – No species were shared exclusively between the Atlantic Forest or Humid Chaco, but *Adenomera diptyx* (Leptodactylidae), *Scinax squalirostris* (Hylidae) and *Phyllomedusa azurea* (Hylidae) have been previously reported from both of those ecoregions but not from the Cerrado ecoregion. Faunal overlap with the Atlantic Forest ecoregion is high (87,5 %) and considerable with the Humid Chaco (75 %). The total influence of each of these ecoregions however shows that there is a much greater influence of the Atlantic Forest (56 %) than the Humid Chaco (40,7 %) on the RNLB amphibian fauna.

e) *Species shared with Atlantic Forest and Cerrado but not with the Humid Chaco.* – Three species recorded at RNL Boccur in Atlantic Forest and Cerrado but not in Humid Chaco: *Siphonops paulensis* (Siphonopidae), *Physalaemu scentralis* (Leiuperidae) and *Chiasmocleis albopunctata* (Microhylidae). No species occur in Humid Chaco and Cerrado but not in Atlantic Forest. Faunal overlap for Humid Chaco species with Atlantic Forest species is thus 100 % in regards to the species present at RNLB.

f) *Species shared with Cerrado, Atlantic Forest and Humid Chaco ecoregions, but which are not generalist species.* – Six species occur in these three eco–regions but do not qualify as generalist species: *Dendropsophus minutus* (Hylidae), *Scinax fuscomarginatus* (Hylidae), *Leptodactylus labyrinthicus* (Leptodactylidae), *Leptodactylus mystacinus* (Leptodactylidae), *Odontophrynus cf. americanus* (Cycloramphidae) and *Eupemphix nattereri* (Leiuperidae). Only *L. labyrinthicus* occurs solely in the three ecoregions and in no other.

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However caution is required over the inclusion of *Odontophrynus cf. americanus* and *Leptodactylus mystacinus* in this category as these species apparently represent cryptic species complexes in Paraguay and several species may be involved (D. Baldo pers. comm. in Smith *et al*., 2016).

g) *Species shared with Mesopotamian Grassland/Pampas, Pantanal, Dry Chaco or Caatinga.* – No species were shared exclusively with the Mesopotamian Grassland/Pampas, Pantanal or Caatinga ecoregions, or any combination of those three. Amongst these three ecoregions, amphibian faunal overlap is greatest with Pantanal (53,1 %) and least with Caatinga (28,1 %) approximately reflecting geographic distance.

DISCUSSION

Similarity of amphibian species composition is predictably greatest with the ecoregions that transition through the RNLB catchment area (Cerrado, Atlantic Forest and Humid Chaco), and decreases with geographical distance from the study site. The near complete amphibian faunal overlap with the Cerrado (90.6%) coupled with the presence of Cerrado endemic species might initially suggest that the amphibian fauna is essentially Cerrado in its composition, however amphibian faunal overlap with the Atlantic Forest is also high (87,5 %). The difference in the influence of these two ecoregions is principally related to the presence of Cerrado endemics and the absence of any other ecoregion endemic in the RNLB amphibian fauna.

Lavilla & Brusquetti (2010) report just 27 species from the Cerrado zone of Paraguay, including five species not recorded at RNLB: the Cerrado endemic *Dendropsophus elianae* (Hylidae); *Phyllomedusa sauvagii* (Hylidae); *Leptodactylus furnarius* (Leptodactylidae); *Rhinella icterica* (Bufonidae) and *Melanophryniscus fulvoguttatus* (Bufonidae). Ten species present at Laguna Blanca have not been reported from the Paraguayan extension of the Cerrado ecoregion: *Siphonops paulensis* (Siphonopidae), *Dendropsophus minutus* (Hylidae), *Scinax squalirostris* (Hylidae), *Phyllomedusa azurea* (Hylidae), *Adenomera diptyx* (Leptodactylidae), *Leptodactylus chaquensis* (Leptodactylidae), *Leptodactylus mystacinus* (Leptodactylidae), *Odontophrynus cf. americanus* (Cycloramphidae), *Physalaemus marmoratus* (Leiuperidae) and *Elachistocleis matogrosso* (Microhylidae; Smith *et al*., 2011; Brouard *et al*., 2016). The latter is generally considered a Cerrado endemic.

Colli *et al*. (2002) reported high endemism of amphibians in the Cerrado ecoregion, with 32 of 113 species (28,3 %) of amphibians considered endemic across the entire ecoregion. However, endemism in Paraguay, the southern extent of the ecoregion, is much lower with just five endemic species (13,5 %) amongst the 37 known to occur in this ecoregion.

A total of 50 species are known from the Atlantic Forest of Paraguay (Lavilla & Brus-

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quetti, 2010). Four species present at Laguna Blanca have not been reported previously from the Paraguayan Atlantic Forest ecoregion, all of these being Cerrado endemics: *Dendropsophus jimi* (Hylidae), *Physalaemus marmoratus* (Leiuperidae), *Rhinellascitula* (Bufonidae) and *Elachistocleis matogrosso* (Microhylidae).

A total of 59 species are known from the Humid Chaco of Paraguay (Lavilla & Brusquetti, 2010). Eight species present at Laguna Blanca have not been reported previously from the Paraguayan Humid Chaco ecoregion: *Siphonops paulensis* (Siphonopidae), *Dendropsophus jimi* (Hylidae), *Hypsiboas albopunctatus* (Hylidae), *Physalaemus centralis* (Leiuperidae), *Physalaemus marmoratus* (Leiuperidae), *Rhinella scitula* (Bufonidae), *Chiasmocleis albopunctata* (Microhylidae) and *Elachistocleis matogrosso* (Microhylidae).

Three species that occur in the neighboring Atlantic Forest and Humid Chaco zones, *Adenomera diptyx* (Leptodactylidae), *Scinax squalirostris* (Hylidae) and *Phyllomedusa azurea* (Hylidae) but had not been previously recorded from the Cerrado ecoregion, demonstrate that these ecoregions do influence on the local amphibian fauna of RNLB. However, all of the 22 species that the Humid Chaco shares with RNLB were also shared with the Atlantic Forest ecoregion (including all 16 generalist species), and the amphibian faunal influence of the Atlantic Forest (56 %) is significantly greater than that of the Humid Chaco (40,7 %).

The fact that the influence of the Cerrado is >100 % implies that the inventory of the Paraguayan Cerrado is far from complete. However, even when the 10 additional species reported at Laguna Blanca that had not been previously reported for the Cerrado ecoregion in Paraguay are included in the calculation (meaning a total of 37 species present in the Paraguayan Cerrado), the influence of the Cerrado ecoregion is still high (86,5 %, 32/37 species). Geographically, Laguna Blanca is located within the Atlantic Forest ecoregion however, and if similar allowances are made for the Atlantic Forest and the 4 species not previously recorded in that ecoregion are included within the influence calculation, then the influence of that ecoregion remains much lower at 59,3 % (32/54 species). Similarly including the 8 species not previously documented in the Humid Chaco in the calculations for that ecoregions till confirms a limited influence on the local amphibian fauna at 47,8% (32/67 species).

CONCLUSIONS

Though geographically RNLB is located in the Atlantic Forest ecoregion, the dominant ecoregional influence at the site is Cerrado. The presence of Cerrado endemics and the influence of the Cerrado being >100 % suggests that the locality should be treated as a southern fragment of the Cerrado ecoregion within the Atlantic Forest zone. This

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conclusion is maintained even when allowing for insufficient sampling by re–analyzing the influence data by attributing the species not previously recorded in each of the potential participating ecoregions as part of their amphibian fauna.

The results presented here demonstrate the utility of local scale biogeographical analysis over regional or continental scale analyses which necessarily over–simplify the complexity of biogeographical patterns. Such analyses are a recommended tool for conservation planners, land managers and biologists at the national level when seeking to designate priority areas for conservation and identify potential areas of endemism in under–sampled regions.

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