



## CONSERVATION IMPLICATIONS OF PROTECTED AREAS' COVERAGE FOR PARAGUAY'S REPTILES

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### ABSTRACT

In Paraguay the highest rate of deforestation was reached in the 2000s, and in some places protected areas are the only remnant of the original ecosystem structure. Paraguay currently has 57 protected areas amounting to 15.2 per cent of the country under protection. In this paper we assess the effectiveness of the Paraguayan system of protected areas (SINASIP) for reptiles' conservation. We generate a matrix of taxa × areas according to 1,789 records for 182 taxa. Areas with the highest number of documented species were *Reserva Ecológica Banco San Miguel y Bahía de Asunción* and *Reserva de Recursos Manejados Ñu Guazú*. Eleven protected areas showed no records. Some species are widely distributed in the country and present in several protected areas, but in other cases numerous species have never been recorded in the protected areas. Three nationally (*Phalotris nigrilatus*, *Philodryas agassizii*, and *Rhachidelus brazili*) and one globally (*Philodryas livida*) threatened species are currently without protection in Paraguay, as well as the endemic species *Homonota rupicola*, *Ophiodes luciae*, *Phalotris normanscottii*, and *Phalotris nigrilatus*. At present 90.1 per cent of the total reptiles are found in at least one protected area in the country. Additionally, we show how sampling effort is biased and concentrated around the capital city; and thus a better systematic sampling of the whole country should be considered. Beyond the legal protection provided by protected areas and the strategies to conserve species and their populations, an analysis of the effectiveness of protected areas should be undertaken to secure conservation in perpetuity.

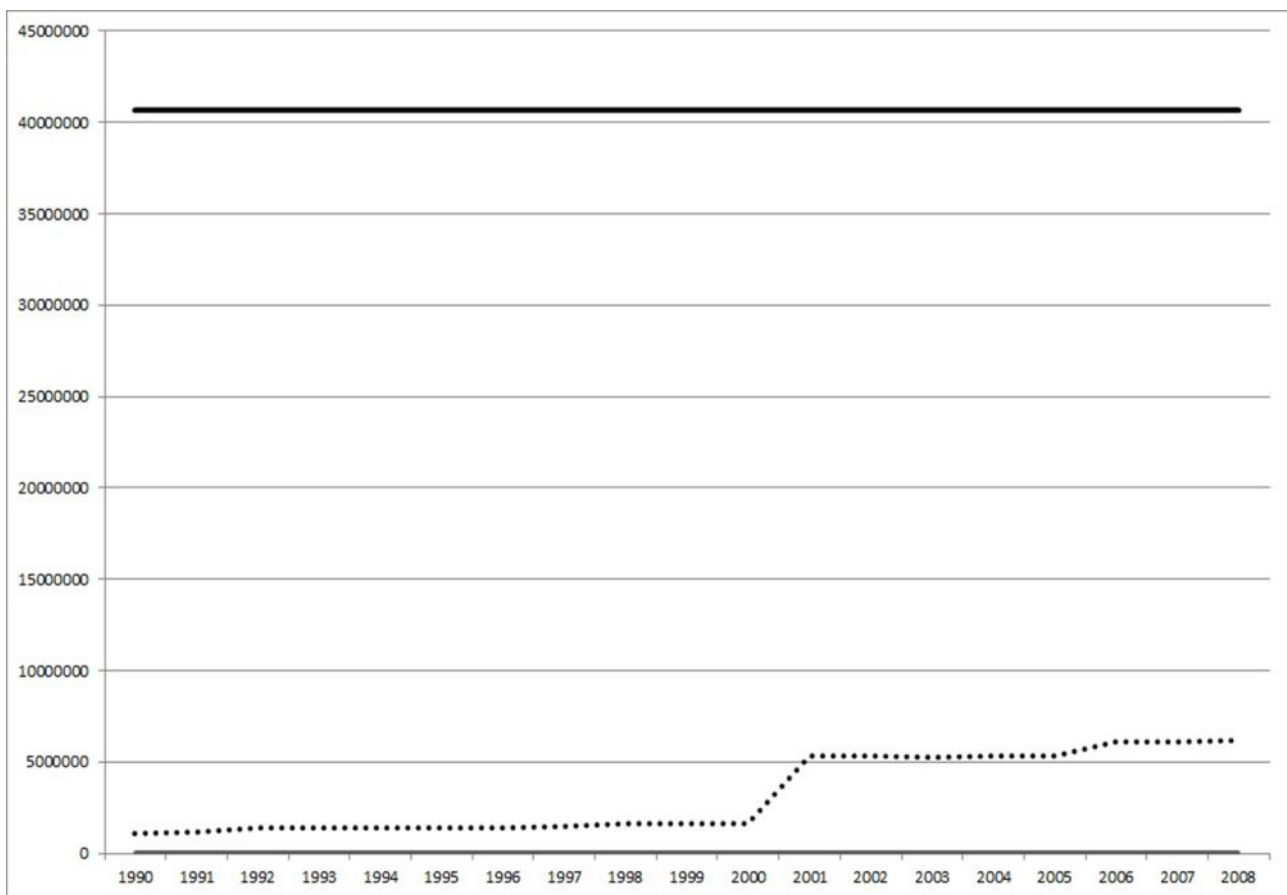
**Key words:** collecting effort, deforestation, endemism, SINASIP, threatened species.

### INTRODUCTION

Protected areas were created as a tool for conserving samples of biological diversity, in the face of the growing crisis of species extinction and the loss of the planet's natural capacity to support human existence as well as the rest of biodiversity (Lopoukhine, 2008). Beyond the role of environmental protection and preservation of natural heritage, protected areas provide additional functions such as contributing to improve human quality of life through poverty reduction, food improvement, and water purification (Dudley & Stolton, 2008; Mansourian et al., 2008; Scherl & Emerton, 2008). Nevertheless, the main objective of any protected area is to protect a representative sample of natural environmental features or certain biodiversity processes of a particular biotic unit (Palacios, 2007).

There are places in the world where human activity places an enormous pressure on the environment – converting natural habitats to productive field crops –

leaving protected areas as the only remnant of an original ecosystem structure (Possingham et al., 2007). A specific example is the Alto Parana Atlantic Forest in Paraguay: this ecoregion has suffered significant loss of cover due to deforestation, and by 2003 only 13.4 per cent of the original cover remained (Di Bitetti et al., 2003), with forest loss reaching its highest rate by the 2000s (Cartes, 2003). In the early 1970s, 73.4 per cent of the ecoregion was covered by forest; since then, the proportion of forested area was quickly reduced to 40.7 per cent by 1989 and further declined to 24.9 per cent by 2000. Paraguay's loss of nearly two thirds of its Atlantic forest between 1973 and 2000, is attributed to two competing deforestation processes: one by settlers and the other by large land owners, with the latter being far more devastating (Huang et al., 2007). In general, protected areas slowed down forest loss within their boundaries; while nearly 40 per cent of Paraguay's Atlantic forests that existed in 1989 were lost by 2000, most protected areas, especially the private ones, lost only small



**Figure 1: Evolution of protected land area in Paraguay. Black line indicates the area of Paraguay (40,675,200 ha), and dotted line the increase in protected areas to a maximum of 6,170,201 ha, which represents 15.2 per cent of the national territory**

proportions of their forest during the same period. However, many of these protected areas remain as isolated ecological islands due to lack of connectivity (Huang et al., 2007).

In an attempt to assess the importance of global ecoregions for conservation, Myers et al. (2000) analyzed the loss of original habitats worldwide and the diversity of endemism in each ecoregion, giving rise to the concept of 'Hot Spots'. In fact, the Atlantic Forest –mentioned previously– and the Cerrado (also present in Paraguay) are considered global hotspots for biodiversity.

Nevertheless, deforestation is not restricted to these ecoregions, and is impacting other forest ecoregions throughout Paraguay. Yanosky (2013) and Bragayrac (2014) showed the negative impact of land use change on the environment and native people in the Chaco. The Gran Chaco Ecoregion (shared with Argentina, Paraguay and Bolivia) is suffering the highest rates of deforestation and protected areas are also being directly affected (Caballero et al., 2014).

The Paraguayan government created the first protected area in 1948 (National Reserve *Cerro Lambaré*), but it was not until 1963 when it first used the term National

Park. Many years later, in 1994, the *Sistema Nacional de Áreas Silvestres Protegidas* (National System of Protected Areas – SINASIP hereafter) was created (Law N° 352/94). Each protected area should have (by law) a core area intended for conservation and a buffer area with the function of reducing negative anthropogenic impacts from outside. This last area is important to prevent or minimize the border effect, and this is the area where activities for the sustainable use of natural resources should be promoted with some specific land-use restrictions. Paraguayan legislation makes the creation of a buffer zone around each protected area mandatory (Law N° 352/94 '*De Áreas Silvestres Protegidas*'). However the actual situation is different, and there are many cases in which the edge of a protected area is abruptly marked by a severe environmental alteration and the absence of ecotones.

Paraguay hosts 30 publically protected areas and 27 in private administration (SEAM, 2009), totalling 6,170,201 ha (or 15.2 per cent of the national territory under legal protection) (Figure 1). The same author states that 58 per cent of the total species of reptiles in the country are protected by SINASIP. Together with fish, reptiles are the least protected groups of vertebrates (SEAM, 2009) (Table 1).

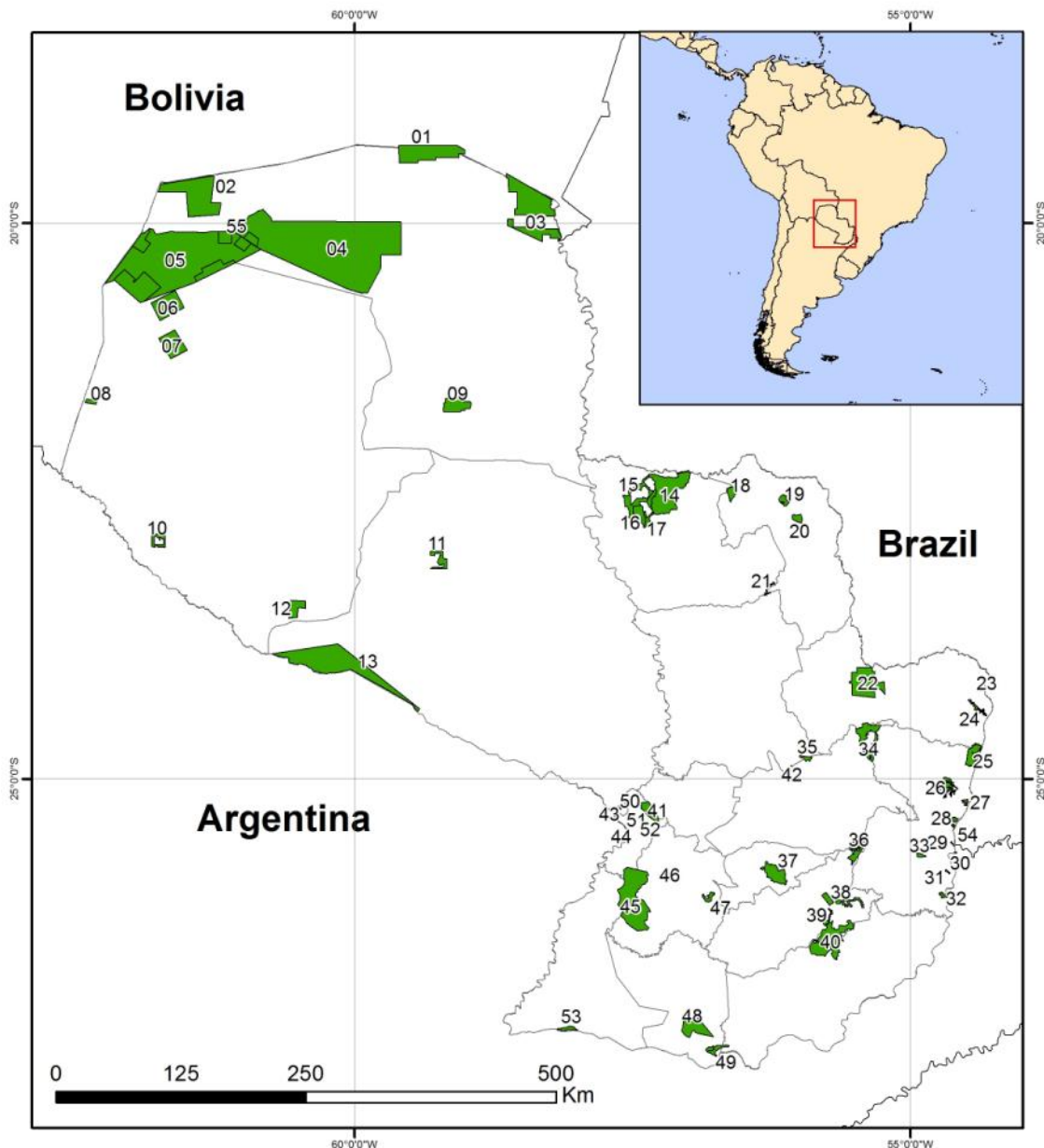
**Table 1: Number of vertebrates known for Paraguay (Count), and number present in any protected area of the SINASIP, and percentage of protection for each taxa (based on SEAM, 2009). Reptiles and fishes are the least protected taxa.**

Taxa	Count	SINASIP	%
Mammals	194	142	73.1
Birds	700	541	77.2
Reptiles	171	99	57.8
Amphibians	81	64	79.0
Fishes	261	151	57.8

The objective of this paper is to assess the contribution of the SINASIP to conserving reptiles, and to identify species that are currently not protected by the Paraguayan protected areas system, or areas where more scientific research and sampling should be carried out.

## METHODS

Paraguay recognizes nine different management categories for conservation areas (Scientific Reserve, National Park, Natural Monument, Wildlife Refuge, Protected Landscapes, Reserve of Managed Resources, Ecological Reserve, Nature Reserve, and Biosphere Reserve). For the purpose of this study we will refer to Protected Areas for all these categories. Officially, the Paraguayan Government recognizes 57 protected areas, ([seam.gov.py/images/stories/seam/sinasip/mapa\\_actualizado\\_de\\_sinasip.pdf](http://seam.gov.py/images/stories/seam/sinasip/mapa_actualizado_de_sinasip.pdf)), which were the focus of this study (Figure 2, Appendix I). Nevertheless, we were not able to obtain information for two new reserves which are not yet legally gazetted: *Reserva Natural de Patrimonio Ayoreo Punie Paseoi* and *Refugio Biologico Yvyty Rokai*. Additionally we made a search on the Protected Planet website ([www.protectedplanet.net/](http://www.protectedplanet.net/) accessed on 1 September 2015) and found that the



**Figure 2: Map of Paraguay showing areas under legal protection. See Appendix I for a key to the numbers**

Taxa	Loc.	Glo.	Protection
<i>Phrynops williamsi</i>	VU	NE	1
<i>Salvator duseni</i>	VU	NE	6
<i>Bachia bresslaui</i>	VU	VU	1
<i>Cercosaura ocellata</i>	VU	NE	2
<i>Liolaemus azarai</i>	VU	NE	1
<i>Boa constrictor amarali</i>	VU	NE	6
<i>Epicrates crassus</i>	VU	NE	2
<i>Drymoluber brazili</i>	VU	NE	1
<i>Hydrops caesurus</i>	VU	LC	2
<i>Mussurana quimi</i>	VU	NE	1
<i>Oxyrhopus petola</i>	VU	NE	5
<i>Phalotris nigrilatus</i>	VU	NE	0
<i>Micrurus corallinus</i>	VU	NE	7
<i>Micrurus lemniscatus</i>	VU	LC	1
<i>Norops meridionalis</i>	EN	NE	1
<i>Dipsas bucephala</i>	EN	NE	4
<i>Imantodes cenchoa</i>	EN	NE	5
<i>Philodryas agassizii</i>	EN	NE	0
<i>Philodryas livida</i>	NE	VU	0
<i>Sibynomorphus mikanii</i>	EN	NE	3
<i>Paleosuchus palpebrosus</i>	CR	LC	1
<i>Eunectes murinus</i>	CR	NE	1
<i>Rhachidelus brazili</i>	CR	LC	0
<i>Bothrops jararacussu</i>	CR	LC	4

Table 2: Threatened reptiles in Paraguay (Nat.) after Motte et al. (2009), with the global conservation status (Glo.). Although *Philodryas livida* was NE nationally, it is included because globally it is considered VU. In 'Protection' we indicate the number of protected areas in which those taxa are present. In bold are threatened taxa without protection.

website is in need of updating and some areas (Lago Ypoá, Río Negro, and Tinfunqué) are listed twice; so information available there cannot be used for the Paraguayan protected areas.

We took the base species list from [www.reptile-database.org](http://www.reptile-database.org), with some modifications; and follow Carvalho (2013) who does not consider *Tropidurus guarani* a Paraguayan endemic. Given that the distributions of *Kentropyx striata* and *Thamnodynastes pallidus* are geographically distant from Paraguay (Gallagher & Dixon, 1992; Bailey et al., 2005), we will not consider it to be present in the country until the publication of evidence confirming the Paraguayan records. In the case of *Xenodon newwiedi* there are some historical references without specific data (Bertoni, 1939; Gatti, 1955; Talbot, 1979), so we did not include this taxon in the analysis. Until there is a more clear definition of the *Bothrops newwiedi* group, we refer to Paraguayan populations as *B. diporus*.

Reptile locality records were taken from Cacciali et al. (2015) and Cabral and Weiler (2014), with the following taxonomic modifications: we recognize subspecies of *Boa*

*constrictor* (*B. c. amarali* and *B. c. occidentalis*) and *Oxyrhopus rhombifer* (*O. r. rhombifer* and *O. r. inaequifasciatus*) as different taxa. Additionally, *Erythrolamprus poecilogyrus* was treated as: *E. p. caesius*, *E. p. schotti*, and *E. p. caesius* × *E. p. schotti*. Additional locality records are based on Cacciali (2011) for *Leptodeira annulata*, Cacciali (2013) for *Philodryas patagoniensis*, *Sibynomorphus turgidus*, *Bothrops alternatus*, and *Crotalus durissus*, and Entiauspe-Neto et al. (2014) for *Apostolepis intermedia*. Records of *Phalotris* in Paraguay were based on Cabral and Cacciali (2015).

The exotic lizard *Hemidactylus mabouia* was excluded from the analysis given that it is an introduced species associated with human habitation and has no conservation value in the country. Also, where species are lacking specific geographical information they were excluded from the analysis, such as *Chironius exoletus* and *Lygophis anomalus*.

It is important to note that we based our records on published papers which had made an adequate study of specimens, and we avoid the use of databases because





**Left: Kue Tuvy Indigenous Reserve: A common environmental feature observed in protected areas in Paraguay is lack of ecotone © Andrea Ferreira. Right: Caazapá National Park: Another problem often observed is the lack of buffer zones, here patches of protected forest are isolated among a matrix of field crops © Hugo Cabral**

specimens are often erroneously identified leading to incorrect interpretations of the data (Hjarding et al., 2015). Presence records were used to generate a matrix of taxa × areas (Soberón, 2015), where ‘taxa’ refers to any species or subspecies recorded in Paraguay, and ‘areas’ corresponds to the existing 55 protected areas in Paraguay. Maps were generated using GPS TrackMaker v.13.9 and ArcGis 10. We differentiated two kinds of records on protected areas: ‘Confirmed’ records when a given locality record for a taxa falls within the borders of protected areas (black squares in Appendix I), and ‘Adjacent’ presence when a record came from the area surrounding the protected area ( $\approx 20$  km or less) (white squares in Appendix I).

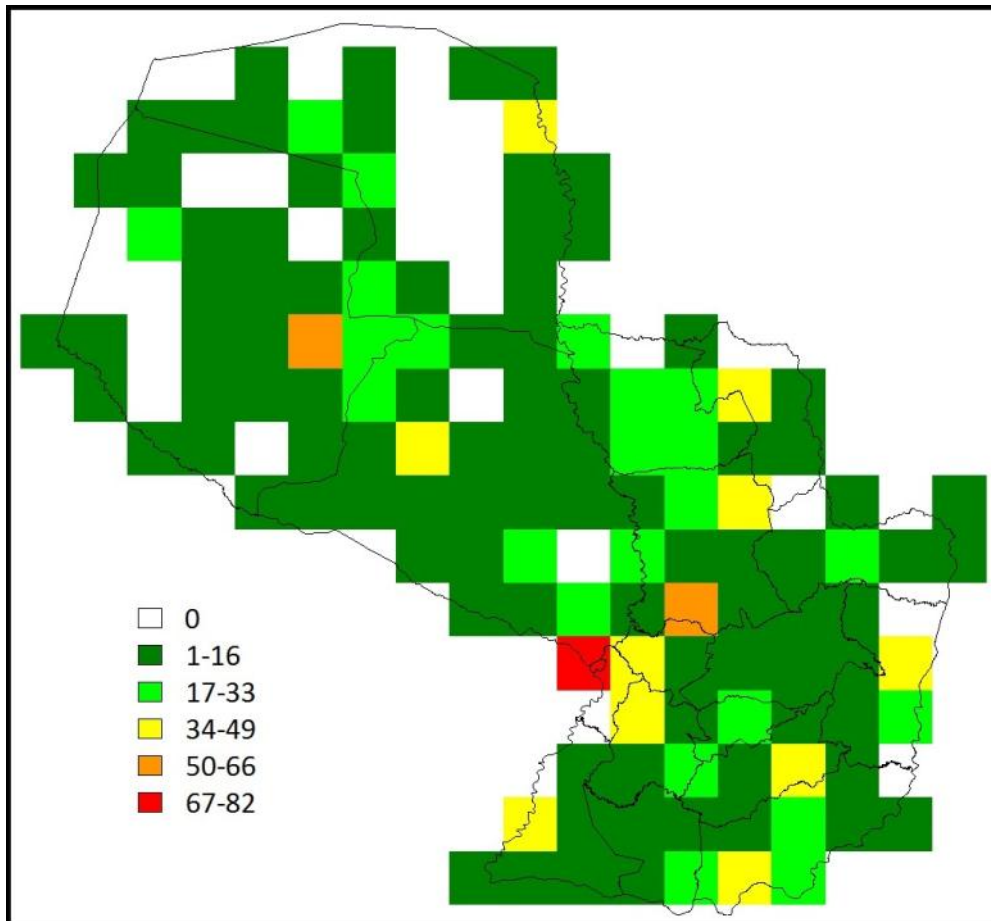
The national conservation status of each species (when available) is based on Motte et al. (2009) who followed the IUCN criteria. Global extinction risk is according to IUCN (2014). According to Motte et al. (2009), in Paraguay 14 reptile species are VU classified, six are EN, and four are CR (Table 2). *Bachia bresslaui* and *Philodryas livida* (this last not assessed by Motte et al., 2009) are the only regionally threatened species (VU after IUCN, 2014).

Finally, given that this analysis is based on collections and not on a systematic sampling across Paraguay, there could be some biases in the sampling effort, with some areas without samples, and others oversampled. To illustrate this effect, we plotted the records on a Paraguayan map with DIVA-GIS ver. 7.5, and we then analyzed the species richness with the transformation of ‘Point to Grid’ through simple grouping aggregation. The class intervals were automatically generated dividing the highest number of occurrences per grid by five intervals per class. We used a grid size of half a longitudinal degree ( $\sim 51$  km) by half a latitudinal degree ( $\sim 55$  km), anchored in the right lower corner.

## RESULTS

A total of 1,789 record points were analyzed for 182 taxa (Appendix I). We found 467 confirmed records and 307 adjacent records of reptiles in Paraguayan protected areas (Appendix I). The areas with the most species recorded were *Reserva Ecológica Banco San Miguel y Bahía de Asunción* (41 confirmed and 17 adjacent) and *Reserva de Recursos Manejados Ñu Guazú* (25 confirmed and 29 adjacent). These two areas resulted in more than 50 confirmed records from protected areas in the vicinity of Asunción. The protected area with the third largest number of confirmed species is *Parque Nacional Defensores del Chaco* (40 confirmed and 2 adjacent), followed by *Reserva Natural Yacyreta* (38 confirmed), *Parque Nacional Río Negro* (33 confirmed and 7 adjacent), and *Parque Nacional Cerro Corá* (37 confirmed and 1 adjacent). Eleven protected areas showed no records (Appendix I).

Some species are widely distributed throughout the country and present in several protected areas (*Notomabuya frenata*, *Ameiva ameiva*, *Xenodon merremi*, and *Salvator merianae*). In other cases, numerous species have never been recorded in protected areas (nor adjacent to them), such as: *Amphisbaena steindachneri*, *A. trachura*, *Chironius exoletus*, *Homonota rupicola*, *Lygophis meridionalis*, *Micrurus lemniscatus carvalhoi*, *Ophiodes luciae*, *Oxyrhopus rhombifer rhombifer*, *Phalotris matogrossensis*, *Phalotris normanscotti*, *P. nigrilatus*, *Philodryas agassizii*, *P. livida*, *Phimophis guerini*, *Phrynosoma hilarii*, *Psomophis obtusus*, *Rhachidelus brazili*, and *Xenodon histricus*. It is important to highlight that *Amphisbaena albocingulata*, *Homonota rupicola*, *Ophiodes luciae*, *Phalotris normanscotti*, and *P. nigrilatus* are endemic to Paraguay, and so their absence from Paraguayan protected areas is particularly worrying.



**Figure 3:** Grid of Paraguay showing species richness. As can be seen, most of the collection effort is focused around Asunción (capital city of Paraguay), the only red area. Several areas still remain unknown (white spaces). Colours reflect the number of species in each grid

With respect to the threatened taxa, three do not occur in any protected areas: *Phalotris nigrilatus*, *Philodryas agassizii*, and *Rhachidelus brazili* categorized as VU, EN, and CR in Motte et al. (2009) respectively. Regarding the total number of taxa analyzed, 18 are not found in protected areas, comprising 9.9 per cent of all reptile taxa found in Paraguay. Of the total number of species 90.1 per cent are found in at least one protected area of the SINASIP, or in adjacent areas.

Regarding sampling bias, we found that the grid with the highest number of occurrences, 82, is located in the area of Asunción, while several grids lack any information at all (Figure 3).

## DISCUSSION

Paraguayan reptile diversity is poorly known. Collecting efforts are not representative and they do not truly represent the biogeographic patterns of the country (Cacciali & Ubilla, 2015). The *Reserva Ecológica Banco San Miguel y Bahía de Asunción* and *Reserva de Recursos Manejados Ñu Guazú* are both located in the surroundings of Asunción (capital city of Paraguay), and benefit from more intensive collecting efforts than other areas. Cacciali and Ubilla (2015) found that the highest 'diversity' hotspots for reptiles in Paraguay are: Asunción, Colonia Primavera (many collections between

1956 and 1971 in San Pedro Department at 24°27'S, 57°09'W), Filadelfia (main city of Paraguayan Chaco and capital of Boquerón Department at 22°21'S, 60°06'W), *Parque Nacional Defensores del Chaco*, and Yacyreta Island (here referred to as *Reserva Natural Yacyreta*). Thus, protected areas with a high number of confirmed records match with areas that have been well sampled, and they do not necessarily represent areas of high biodiversity.

Areas without confirmed records include *Monumento Natural Cerro Chovoreca*, *Reserva Natural Cerro Cabrera/Timane*, *Reserva Natural Cañada del Carmen*, *Reserva Natural Carapá*, *Reserva Natural Tabucay*, *Reserva para Parque Nacional Ñacunday*, *Reserva Ecológica Capiibary*, *Monumento Natural Cerro Chororí*, *Monumento Natural Cerro Koi*, *Isla Carrizal*, *Reserva Nacional Saltos del Guaira*, and *Reserva Natural Lote 1*. The lack of information from these areas is due to the difficulty of access or because no scientific collections were made during ecological assessments.

Based on this information, we conclude that 90.1 per cent of Paraguayan reptiles are under protection in protected areas. Nonetheless, some threatened or endemic species have not been recorded in protected areas. That is the case of the locally threatened snakes





***Philodryas livida* a globally threatened snake: there has been only one record in Paraguay, which was not in a protected area**  
© Para La Tierra

*Philodryas agassizii* (EN) and *Rhachidelus brazili* (CR), two species that are poorly known in the country, or even worse the globally threatened *Philodryas livida*. This last species was not evaluated by Motte et al. (2009). Currently NatureServe and other institutions have been advancing Red List assessments for squamates, and there is already a complete assessment for the Western Hemisphere (Young, 2012). The global assessment of the conservation status of the species present in Paraguay would have important potential implications for further conservation actions in the country, given that currently only 28 species of Paraguayan reptiles are assessed, four of them threatened: *Acanthochelys pallidipectoris*, *Bachia bresslaui*, *Chelonoidis chilensis*, and *Philodryas livida*, but this last is not included for Paraguay (IUCN, 2014). Endemic reptiles in Paraguay are *Amphisbaena albocingulata*, *Homonota rupicola*, *Ophiodes luciae*, *Phalotris normanscottii*, and *Phalotris nigrilatus* (Ferrarezzi, 1993; Cacciali et al., 2007a, b; Perez et al., 2012; Cabral & Cacciali, 2015; Cacciali & Scott, 2015); only the first of these was reported in protected areas.

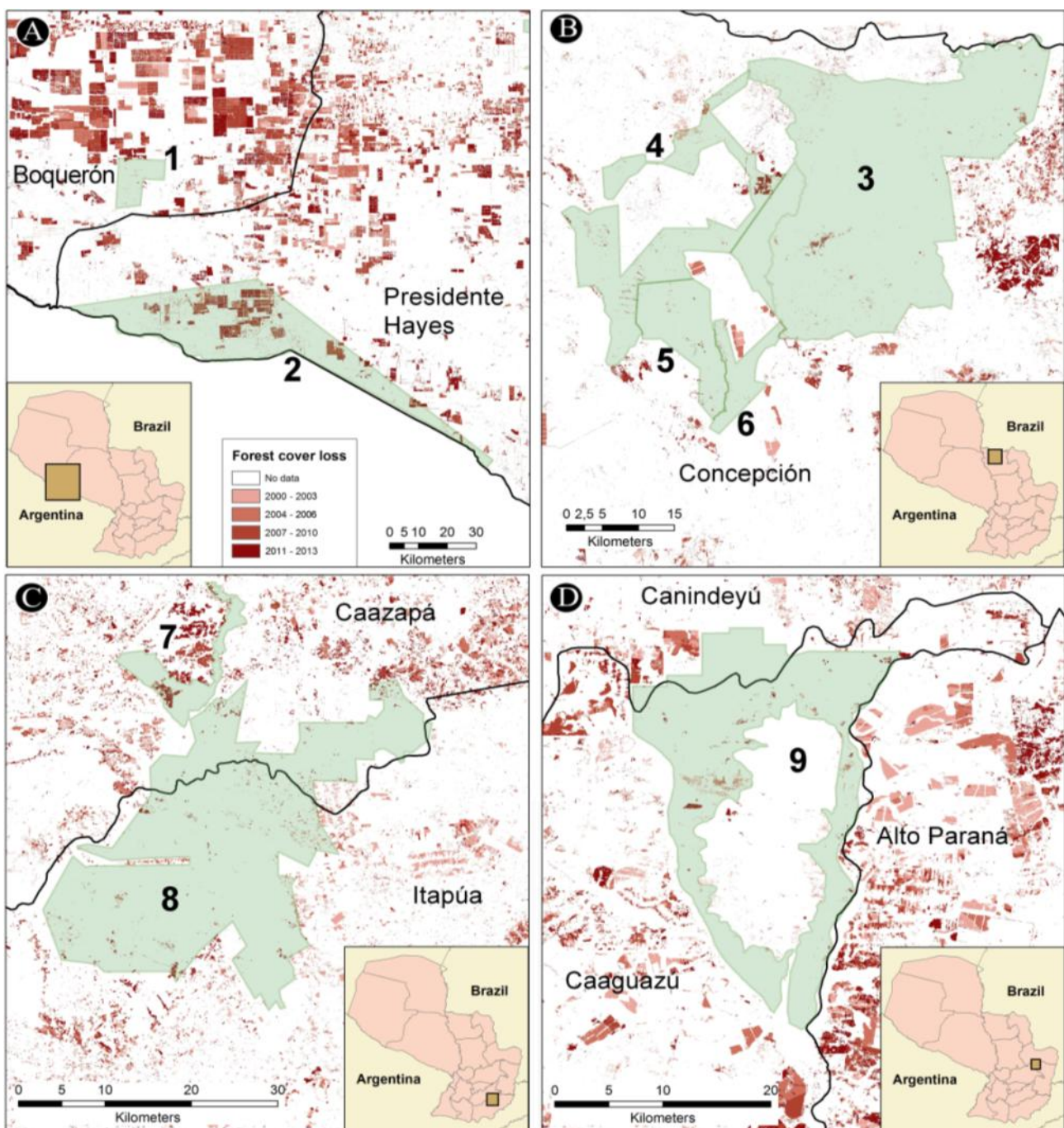
Some species with adjacent records in protected areas include *Paleosuchus palpebrosus*, *Norops meridionalis*, *Liolaemus chacoensis*, *Liotyphlops ternetzii*, *Atractus paraguayensis*, *Phimophis vittatus*, *Xenodon dorbignyi*, and *Micrurus lemniscatus*. All except for *P. palpebrosus* and *M. lemniscatus*, have a wider distribution in the country. *M. lemniscatus* is known only from Campo 9 (Caaguazú Department, at 25°25'S, 55°34'W) at 8.9 km

from *Reserva Natural Ypeti*. In the particular case of *P. palpebrosus*, this is a caiman whose presence in Paraguay seems to be occasional with probably the Río Apa as its southern distribution limit. The species was recorded 30 km SW from Bella Vista (Amambay Department, at 22°15'S, 56°46'W) at 15.7 km from *Parque Nacional Bella Vista*.

The distribution of some reptiles is little known and understood; for example, the ranges of *P. agassizii* and *Tomodon ocellatus* are unknown (Cabral & Caballero, 2013). Some reptiles in Paraguay are only known by one or two records (Cacciali et al., 2015), and in these cases, some protected areas play a crucial role in their conservation, such as *Parque Nacional Cerro Corá* for *Bachia bresslaui*, *Ophiodes fragilis*, and *Chironius flavolineatus*; *Parque Nacional San Rafael* for *Ophiodes* aff. *striatus*, *Atractus thalesdelemai*, and *Micrurus silviae*; *Reserva Natural Yacyreta* for *Mussurana quimi* and *Oxyrhopus rhombifer rhombifer*; *Parque Nacional Defensores del Chaco* for *Homonota* aff. *borelli* and *Sibynomorphus lavillai*; and *Reserva Natural del Bosque Mbaracayú* for *Drymoluber brazili*.

Special attention should be focused on 'Reserva Natural' Laguna Blanca, a small area of 805 ha located in the Department of San Pedro. The area was under temporary protection (legal protection lapsed in February 2015), and was supported by tourism activities and conservation carried out by the NGO, Para La Tierra





**Figure 4.** In Paraguay deforestation sometimes impacts protected areas as can be seen here: A: Reserva Natural Toro Mocho (1), Parque Nacional Tinfunqué (2). B: Parque Nacional Paso Bravo (3), Reserva Natural Tagatiyá mi (4), Parque Nacional San Luis (5), Reserva Natural Cerrados del Tagatiyá (6). C: Reserva Natural Tapytá (7), Parque Nacional San Rafael (8), and Reserva Natural Morombi (9). References to loss of forest cover values shown in A. Deforestation values were taken from Global Forest Watch ([www.globalforestwatch.org/](http://www.globalforestwatch.org/)), accessed on 28 August 2015

([paralatierra.org/index.html](http://paralatierra.org/index.html)). Snakes such as *Lygophis paucidens*, *Philodryas nattereri*, and *P. livida* are only found here (Cacciali et al., 2013; Smith et al., 2013, 2014).

For all these records of threatened, endemic or rare species that fall outside of the protected area network, the focus should be to complete the scientific documentation, looking for alternatives that ensure their protection either through the establishment of new protected areas or through the implementation of 'other

effective area-based conservation measures' (Watson et al., 2014). A useful aspect in this context is the KBAs (Key Biodiversity Areas) approach (Eken et al., 2004; Langhammer et al., 2007), which has already been adopted in Paraguay for birds (Yanosky & Cartes, 2008a, b). In some cases, stronger actions should be taken, given that in most cases the Paraguayan 'Important Bird Areas' (IBAs) match with protected areas (Appendix II); but in those cases that do not match, then the IBAs have no official measures (Cartes & Yanosky, 2008).





**View from Paraguay River in the Paraguayan Pantanal at *Parque Nacional Río Negro*. The property is owned by the association *Guyra Paraguay*; this is the only land in the country declared for perpetual conservation through its titles © Alberto Yanosky**

The increasingly accelerated habitat destruction and fragmentation in different Paraguayan habitat types lead to patches (as occurred with Atlantic Forest *sensu*, Huang et al., 2007) which will lead to the isolation of populations as stated by Smith et al. (2014) for *P. livida*. Paraguay is a global focus of forest loss (Hansen et al., 2013), with a deforestation rate of 179,000 ha per year (FAO, 2010), given the advance of habitat transformation for soy and beef (Guereña & Riquelme, 2013).

All these rural practices make it difficult to conserve natural habitats in Paraguay, and conservationists should look for synergic practices between conservation and development (Naidoo & Ricketts, 2006; Naidoo et al., 2006). In addition, natural protected areas in Paraguay have several problems; the most common and alarming is that the legal size of the areas does not match with reality, the legal area always being reported as bigger. Furthermore, only two areas have management plans (Cartes, 2013). Some protected areas are also affected by deforestation (Figure 4) or other anthropogenic

activities. However, it is important to note that the objective of this paper is not an analysis of the situation of the protected areas' network; instead the aim is to review strategies to conserve species and their populations, nevertheless protected areas require an analysis of their effectiveness to secure their conservation in perpetuity.

Finding reptiles is frequently a matter of luck, this being especially true for snakes (Hartmann et al., 2009). The species mentioned above, as well as many others that are known by few specimens, could have wider distributions and could be present in protected areas; the lack of accurate sampling being responsible for this shortage in knowledge. In Figure 3, it is possible to see how sampling effort is biased in areas surrounding the capital city of Paraguay, with other zones completely lacking information. This study thus also highlights possible areas which should be the object of scientific sampling to generate information about the real effectiveness of protected areas for biodiversity conservation.

## APPENDIX I

List of taxa analyzed in this paper, and their confirmed (■) and probable (□) presence in Paraguayan protected areas. We have used the original área name: **01** Monumento Natural Cerro Chovoreca, **02** Reserva Natural Cerro Cabrera/Timane, **03** Parque Nacional Río Negro, **04** Parque Nacional Defensores del Chaco, **05** Parque Nacional Médanos del Chaco, **06** Reserva Natural Ñu Guazú, **07** Parque Nacional Teniente Enciso, **08** Reserva Natural Cañada del Carmen, **09** Reserva Natural Yaguareté Porã, **10** Reserva Natural Palmar Quemado, **11** Reserva Natural Salazar, **12** Reserva Natural Toro Mocho, **13** Parque Nacional Tinfunqué, **14** Parque Nacional Paso Bravo, **15** Reserva Natural Tagatiyá mi, **16** Parque Nacional San Luis, **17** Reserva Natural Cerrados del Tagatiyá, **18** Parque Nacional Bella Vista, **19** Reserva Natural Arroyo Blanco, **20** Parque Nacional Cerro Corá, **21** Reserva Natural Ka'i Ragüe, **22** Reserva Natural del Bosque Mbaracayú, **23** Refugio Biológico Binacional Mbaracayú, **24** Reserva Natural Carapá, **25** Reserva Ecológica Limoy, **26** Reserva Ecológica Itabó, **27** Reserva Natural Pikyry, **28** Reserva Natural Tati Yupi, **29** Reserva Natural Maharishi, **30** Monumento Científico Moisés Bertoni, **31** Reserva Natural Tabucay, **32** Reserva para Parque Nacional Ñacunday, **33** Reserva Nacional Kuri'y, **34** Reserva Natural Morombi, **35** Reserva Ecológica Capiibary, **36** Reserva Natural Ypeti, **37** Reserva de Recursos Manejados Yvyturuzú, **38** Parque Nacional Caazapá, **39** Reserva Natural Tapytá, **40** Parque Nacional San Rafael, **41** Parque Nacional Lago Ypacaraí, **42** Paisaje Protegido Cerro 2 de Oro, **43** Reserva Ecológica Banco San Miguel y Bahía de Asunción, **44** Reserva Nacional Cerro Lambaré, **45** Parque Nacional Lago Ypoá, **46** Monumento Natural Macizo Acahay, **47** Parque Nacional Ybucuí, **48** Refugio de Vida Silvestre Yabebyry, **49** Reserva Natural Yacyreta, **50** Reserva de Recursos Manejados Ñu Guazú, **51** Monumento Natural Cerro Chororí, **52** Monumento Natural Cerro Koi, **53** Isla Carrizal, **54** Reserva Nacional Saltos del Guaira, **55** Reserva Natural Lote 1.

Taxa ▼	ASPs ▶	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
<i>Acanthochelys macrocephala</i>				■	■							■																
<i>Acanthochelys pallidipectoris</i>												■																
<i>Hydromedusa tectifera</i>																												
<i>Mesoclemys vanderhaegei</i>																						■		■				
<i>Phrynops Geoffroanus</i>																												
<i>Phrynops hilairei</i>																												
<i>Phrynops williamsi</i>																												
<i>Kinosternon scorpionoides</i>					■							□																
<i>Chelonoidis carbonaria</i>			□	■								■			□	■	□											
<i>Chelonoidis chilensis</i>		□		■	□			■				□		■														
<i>Caiman latirostris</i>											□												■			■	■	□
<i>Caiman yacare</i>				■								□		■														
<i>Paleosuchus palpebrosus</i>																				□								
<i>Amphisbaena alba</i>											□																	■
<i>Amphisbaena albocingulata</i>																												
<i>Amphisbaena angustifrons</i>									■																			
<i>Amphisbaena bolivica</i>									■																			
<i>Amphisbaena camura</i>											□																	
<i>Amphisbaena leeseri</i>															■	□	□	□										
<i>Amphisbaena mertensi</i>																							■		■			
<i>Amphisbaena prunicolor</i>															■	□	□	□										
<i>Amphisbaena roberti</i>																							■					
<i>Amphisbaena steindachneri</i>																												
<i>Amphisbaena trachura</i>																												
<i>Leposternon microcephalum</i>																							□					
<i>Lygodactylus wetzeli</i>					■																							
<i>Homonota aff. borelli</i>					■	■																						
<i>Homonota fasciata</i>					■	□	□					□		□	□													
<i>Homonota rupicola</i>																												
<i>Phyllopezus pollicaris</i>				■	■	■	□	■				□											■					
<i>Bachia bresslaui</i>																							■					
<i>Cercosaura ocellata</i>																							■		■			
<i>Cercosaura schreibersii</i>				■								□											■				□	□
<i>Colobosaura modesta</i>																							■					
<i>Micrablepharus maximiliani</i>																												
<i>Vanzosaura rubricauda</i>					■				■																			
<i>Iguana iguana</i>				■																								
<i>Anisolepis longicauda</i>																												
<i>Norops meridionalis</i>																									□			
<i>Polychrus acutirostris</i>				■	■		□	■				□				■							■				□	□
<i>Ameiva ameiva</i>				■	■	■	□	■			□	■	■		□	■	■	□					■					
<i>Ameivula abalosi</i>				■	■	■	□	■				■																
<i>Ameivula ocellifera</i>																							■	■	■			
<i>Dracaena paraguayensis</i>				■																								
<i>Kentropyx viridistriga</i>				■																								
<i>Salvator duseni</i>																□	□	■	□				■	■				
<i>Salvator merianae</i>				■				■				□				□	□	□					■		■			
<i>Salvator rufescens</i>				□	■							□	□															
<i>Teiurus oculatus</i>																												
<i>Teiurus teyou</i>			□	■							□	■	□	■										■			■	■
<i>Liolaemus azarai</i>																												
<i>Liolaemus chacoensis</i>													□															
<i>Stenocercus caducus</i>			□	■	■										□	■	□	□					■				■	
<i>Tropidurus catalanensis</i>																											□	□
<i>Tropidurus etheridgei</i>					■	■	□	■				□			□													
<i>Tropidurus guarani</i>																								■				
<i>Tropidurus spinulosus</i>				■	■			■				□	□	□	□	□				□			■					
<i>Aspronema dorsivittatum</i>																									■			
<i>Copeoglossum nigropunctatum</i>				■								□																







<i>Tropidurus guarani</i>										■	■					
<i>Tropidurus spinulosus</i>																
<i>Aspronema dorsivittatum</i>								■	■						■	
<i>Copeoglossum nigropunctatum</i>																
<i>Manciola guaporicola</i>																
<i>Notomabuya frenata</i>	□			■	■	□	■	■	■	■	■	■	■	■		□
<i>Ophiodes fragilis</i>																
<i>Ophiodes intermedius</i>										■	■			■		□
<i>Ophiodes luciae</i>																
<i>Ophiodes striatus</i>							■									■
<i>Ophiodes aff. striatus</i>																
<i>Liotyphlops beui</i>	□															□
<i>Liotyphlops ternetzii</i>																□
<i>Epictia albipuncta</i>																
<i>Epictia munoai</i>											■					■
<i>Rena unguirostris</i>																
<i>Amerotyphlops brongersmanus</i>							□									□
<i>Boa constrictor amarali</i>																
<i>Boa constrictor occidentalis</i>																
<i>Epicrates alvarezii</i>																
<i>Epicrates crassus</i>	□															
<i>Eunectes murinus</i>																
<i>Eunectes notaeus</i>															■	□
<i>Chironius bicarinatus</i>	■	□														
<i>Chironius flavolineatus</i>																
<i>Chironius quadricarinatus</i>																□
<i>Chironius maculoventris</i>																□
<i>Drymarchon corais</i>																
<i>Drymoluber brazili</i>																
<i>Leptophis ahaetulla</i>																
<i>Mastigodryas bifossatus</i>																
<i>Simophis rhinostoma</i>																
<i>Spilotes pullatus</i>	□	□														
<i>Tantilla melanocephala</i>																
<i>Apostolepis ambiniger</i>																
<i>Apostolepis assimilis</i>																
<i>Apostolepis dimidiata</i>																
<i>Apostolepis intermedia</i>																
<i>Atractus thalesdelemai</i>																
<i>Atractus paraguayensis</i>																
<i>Atractus reticulatus</i>																
<i>Boiruna maculata</i>																
<i>Clelia clelia</i>																
<i>Clelia plumbea</i>	□															
<i>Dipsas bucephala</i>																
<i>Dipsas cisticeps</i>																
<i>Erythrolamprus aesculapii</i>																
<i>Erythrolamprus almadensis</i>																
<i>Erythrolamprus frenatus</i>																
<i>Erythrolamprus guentheri</i>																
<i>Erythrolamprus jaegeri</i>																
<i>Erythrolamprus militari</i>																
<i>Erythrolamprus poecilogyrus caesius</i>																
<i>Erythrolamprus p. schotti</i>																
<i>E. p. caesius × L. p. schotti</i>																
<i>Erythrolamprus reginae</i>	□															
<i>Erythrolamprus sagittifer</i>																
<i>Erythrolamprus semiaureus</i>																
<i>Erythrolamprus typhlus</i>																
<i>Helicops infrataeniatus</i>	□															
<i>Helicops leopardinus</i>																
<i>Hydrodynastes gigas</i>																
<i>Hydrops caesurus</i>																
<i>Imantodes cenchoa</i>																
<i>Leptodeira annulata</i>																
<i>Lygophis dilepis</i>																
<i>Lygophis flavifrenatus</i>																
<i>Lygophis meridionalis</i>																
<i>Lygophis paucidens</i>																
<i>Mussurana bicolor</i>																
<i>Mussurana quimi</i>																
<i>Oxyrhopus guibei</i>	■	■														
<i>Oxyrhopus petola</i>	□	□														
<i>Oxyrhopus rhombifer</i>																
<i>Oxyrhopus r. inaequifasciatus</i>																
<i>Phalotris lemniscatus</i>																
<i>Phalotris matogrossensis</i>																
<i>Phalotris nigrilatus</i>																
<i>Phalotris normanscottii</i>																
<i>Phalotris tricolor</i>																
<i>Philodryas aestiva</i>																
<i>Philodryas agassizii</i>																
<i>Philodryas baroni</i>																
<i>Philodryas livida</i>																
<i>Philodryas matogrossensis</i>																
<i>Philodryas nattereri</i>																
<i>Philodryas offersii</i>	□															
<i>Philodryas patagoiensis</i>																
<i>Philodryas psammophidea</i>																
<i>Phimophis guerini</i>																

Taxa ▼	ASPs ▶	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
<i>Phimophis vittatus</i>																													
<i>Pseudoboa nigra</i>																													
<i>Pseudoeryx plicatilis</i>																	■												
<i>Psomophis genimaculatus</i>																													
<i>Psomophis obtusus</i>																													
<i>Rhachidelus brazili</i>																													
<i>Sibynomorphus lavillai</i>																													
<i>Sibynomorphus mikanii</i>		■	□																										
<i>Sibynomorphus turgidus</i>														■			■	□						■	■				
<i>Sibynomorphus ventrimaculatus</i>																	■	■					□	■	■				
<i>Taeniophallus occipitalis</i>																													□
<i>Thammodynastes chaquensis</i>																													■
<i>Thammodynastes hypoconia</i>																													□
<i>Thammodynastes lanei</i>																													■
<i>Thammodynastes strigatus</i>														■															■
<i>Tomodon dorsatus</i>		■	■																										
<i>Tomodon ocellatus</i>																													
<i>Xenodon dorbignyi</i>																													
<i>Xenodon histricus</i>																													
<i>Xenodon merremi</i>		□											■	□	■	□	■	□			■	■	■	■	■				
<i>Xenodon pulcher</i>																													
<i>Xenopholis undulatus</i>																													
<i>Micrurus altirostris</i>																													
<i>Micrurus baliocoryphus</i>																													
<i>Micrurus corallinus</i>		■	■																										
<i>Micrurus frontalis</i>																													
<i>Micrurus lemniscatus carvalhoi</i>																													
<i>Micrurus pyrrhocryptus</i>																													
<i>Micrurus silviae</i>																													
<i>Bothrops alternatus</i>		■																											
<i>Bothrops diporus</i>																													
<i>Bothrops jararaca</i>		■																											
<i>Bothrops jararacussu</i>		■																											
<i>Bothrops moojeni</i>		■																											
<i>Bothrops pauloensis</i>																													
<i>Crotalus durissus</i>																													
<b>Total confirmed</b>		17	9	0	0	0	0	2	0	1	9	5	1	26	8	0	41	8	3	6	21	6	38	25	0	0	0	0	0
<b>Total probables</b>		12	4	1	0	0	2	2	0	2	2	5	11	5	14	1	17	10	2	0	6	8	0	29	0	0	0	0	0

APPENDIX II

Details of some characteristics of the Paraguayan protected areas, such as land area (in hectares), and number of threatened (Thr) and endemic (End) species protected by each area, based on confirmed records only. Also, we include a column to show if the area matches with a Paraguayan IBA. Numbers (left column) correspond to those in Appendix I.

	Protected Area	Land area (ha)	Thr	End	IBA
1	Cerro Chovoreca	100,953	0	0	
2	Cerro Cabrera/Timane	125,823	0	0	
3	Río Negro	123,786	1	0	X
4	Defensores del Chaco	720,000	0	0	X
5	Médanos del Chaco	514,233	0	0	X
6	Ñu Guazú (Boquerón)	50,000	0	0	
7	Teniente Enciso	40,000	0	0	X
8	Cañada del Carmen	3,973	0	0	
9	Yaguareté Porã	78,549	0	0	
10	Palmar Quemado	9,478	0	0	
11	Estancia Salazar	12,450	0	0	
12	Toro Mocho	18,000	0	0	
13	Tinfunqué	241,320	0	0	X
14	Paso Bravo	103,018	0	0	X
15	Tagatiyá mi	33,789	2	0	X
16	San Luis	10,273	1	0	X
17	Cerrados del Tagatiyá	5,700	0	0	X
18	Bella Vista	7,311	0	0	



	Protected Area	Land area (ha)	Thr	End	IBA
19	Arroyo Blanco	5,714	1	0	X
20	Cerro Corá	5,538	4	0	
21	Ka'i Ragüe	1,859	1	0	
22	Mbaracayú (Reserve)	64,405	7	0	X
23	Mbaracayú (Refuge)	1,629	0	0	
24	Carapá	3,658	0	0	X
25	Limoy	13,600	2	0	X
26	Itabó	17,879	2	0	X
27	Pikyry	1,629	4	0	
28	Tati Yupi	2,037	4	0	
29	Maharishi	343	2	0	
30	Moisés Bertoni	200	0	0	
31	Tabucay	559	0	0	
32	Ñacunday	2,000	0	0	
33	Kuri'y	2,000	0	0	
34	Morombi	25,000	0	0	X
35	Capiibary	3,082	0	0	
36	Ypeti	13,592	0	0	X
37	Yvyturuzú	24,000	0	0	
38	Caazapá	16,000	0	0	X
39	Tapytá	4,736	0	0	X
40	San Rafael	72,849	2	0	X
41	Lago Ypacaraí	16,000	0	0	
42	Cerro 2 de Oro	44	0	0	
43	Banco San Miguel	300	0	0	X
44	Cerro Lambaré	3	0	0	
45	Lago Ypoá	100,000	0	0	
46	Macizo Acahay	2,500	0	1	
47	Ybycuí	5,000	0	0	
48	Yabebyry	30,000	0	0	X
49	Yacyreta	8,345	4	0	X
50	Ñu Guazú (Central)	280	0	0	
51	Cerro Chororí	5	0	0	
52	Cerro Koi	12	0	0	
53	Isla Carrizal	4,371	0	0	
54	Saltos del Guaira	900	0	0	
55	Lote 1	5,364	0	0	

## ABOUT THE AUTHORS

**Pier Cacciali** is a biologist with extensive expertise in reptile's taxonomy, biogeography and conservation. He participated in the local assessment of amphibians and reptiles in Paraguay (Motte et al. 2009. Cuad. Herpetol., 23(1):5-18). He was invited to participate in the regional IUCN assessment of Squamata in 2014. He has given several public talks in Paraguay concerning the importance of snakes to the environment. Pier holds an M.Sc. in biology and currently has a Ph.D. position at the Senckenberg Institute in Frankfurt (Germany). He is also an active researcher (level I) of the National Council of Science in Paraguay (CONACYT).

**Hugo Cabral** has worked in conservation since he was 16 years old, and now specializes in herpetology (taxonomy, biogeography and natural history of snakes). In Paraguay he was a volunteer in the National Museum of Natural History, and in the Zoological Collection of the Biology Department of National University, where he took his first steps in herpetology with the help of his mentor Pier Cacciali. Hugo is now enrolled in an M.Sc. degree programme at the Universidad Nacional de Asunción. Currently he is working as Conservation and Biodiversity Officer at the Asociación Guyra Paraguay and is a researcher associated to the Instituto de Investigación Biológica del Paraguay.

**Alberto Yanosky** has a Bachelor Degree in Biology, a Master in Science and Methodology and a Doctorate in Science, has worked in research and conservation for 30 years, published more than 100 scientific contributions, currently CEO for Guyra Paraguay, a biodiversity conservation and research Institute in Paraguay and maximum level researcher for the Paraguayan National Science and Technological Council. He is a lecturer, reviewer and international speaker in conservation, associated with different universities in Postgraduate Studies. He directs young conservation professionals. He is Chief Editor of *Paraquaria Natural* and received the 2013 National Geographic / Buffett Award for Leadership in Conservation in Latin America.

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## RESUMEN

En Paraguay, la tasa más alta de deforestación fue alcanzada en los años 2000, y en algunos lugares las áreas protegidas son el único vestigio de la estructura de los ecosistemas originales. Paraguay cuenta actualmente con 57 áreas protegidas con las que el 15,2 por ciento del territorio nacional está bajo protección. En este trabajo evaluamos la eficacia del sistema de áreas protegidas de Paraguay (SINASIP) para la conservación de los reptiles. Generamos una matriz de taxones × áreas de acuerdo a 1.789 registros para 182 taxones. Las áreas con mayor número de especies documentadas fueron la “Reserva Ecológica Banco San Miguel y Bahía de Asunción” y la “Reserva de Recursos Manejados Ñu Guazú”. Once áreas protegidas no mostraron registros. Algunas especies están ampliamente distribuidas en el país y presentes en varias unidades de conservación; pero en otros casos, numerosas especies nunca han sido registradas en estas áreas. Tres especies nacionalmente amenazadas (*Phalotris nigrilatus*, *Philodryas agassizii* y *Rhachidelus brazili*) y una globalmente amenazada (*Philodryas livida*) están actualmente sin protección en el Paraguay, así como las especies endémicas (*Homonota rupicola*, *Phalotris normanscottii* y *Phalotris nigrilatus*). En la actualidad el 90,1 por ciento del total de reptiles se encuentran en al menos un área protegida en el país. Además, mostramos cómo los esfuerzos de muestreo están sesgados y concentrados en los alrededores de la ciudad capital, y por lo tanto debe considerarse la realización de un muestreo sistemático en el país. Más allá de la protección legal en las unidades de conservación y las estrategias para la conservación de especies y sus poblaciones, las áreas protegidas todavía requieren de un análisis de la eficacia para garantizar la conservación a perpetuidad.

## RÉSUMÉ

Au Paraguay, le plus haut taux de déforestation fut atteint dans les années 2000, et dans certains endroits les aires protégées sont le seul vestige de la structure des écosystèmes originaux. Le Paraguay compte actuellement 57 aires protégées, soit 15,2 % du territoire national sous protection. Dans ce travail nous évaluons l'efficacité du système des aires protégées au Paraguay (SINASIP) pour la conservation des reptiles. Nous avons généré une matrice de taxons × aires protégées en fonction de 1789 dossiers pour 182 taxons. Les aires protégées ayant le plus grand nombre d'espèces documentées sont la "Reserva Ecológica Banco San Miguel y Bahía de Asunción" et la "Reserva de Recursos Manejados Ñu Guazú". Onze aires protégées n'ont pas fourni de registres. Certaines espèces sont largement réparties à travers le pays et sont présentes dans plusieurs aires protégées; mais dans d'autres cas, de nombreuses espèces n'ont jamais été enregistrées dans ces régions. Trois espèces menacées à l'échelle nationale (*Phalotris nigrilatus*, *Philodryas agassizii* et *Rhachidelus brazili*), et une espèce menacée à l'échelle mondiale (*Philodryas livida*), vivent actuellement sans protection au Paraguay, ainsi que des espèces endémiques *Homonota rupicola*, *Ophiodes luciae*, *Phalotris normanscotti* et *Phalotris nigrilatus*. Actuellement, 90,1% des reptiles se trouvent dans au moins une aire protégée du pays. En outre, nous mettons en lumière les limites de l'échantillonnage actuel, qui se trouve concentré autour de la capitale, et démontrons de ce fait le besoin d'un meilleur échantillonnage systématique dans le pays. Au-delà de la protection juridique assurée par des aires protégées et des stratégies pour la conservation des espèces et de leurs populations, une analyse de l'efficacité des aires protégées pour assurer la conservation durable à long terme s'avère nécessaire.