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ARTICLE

Conservation gaps identification through patterns of species richness established from species niche models of mammals in a sector of Chaco Seco ecoregion

Federico Fernando Rivas[1,4] **& María Florencia Speciale**[2,3,5]

[1] Universidad Nacional de Santiago del Estero (UNSE), Facultad de Ciencias Forestales (FSC), Instituto de Protección Vegetal (INPROVE). Santiago del Estero, SE, Argentina.
[2] Universidad Nacional de Santiago del Estero (UNSE), Facultad de Ciencias Forestales (FSC), Instituto de Tecnología de la Madera (ITM). Santiago del Estero, SE, Argentina.
[3] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET). Buenos Aires, D.F., Argentina.
[4] ORCID: 0000-0002-3945-8145. E-mail: oikosfede@gmail.com
[5] ORCID: 0000-0002-3527-0751. E-mail: specialeflor@gmail.com

Abstract. The identification of biodiversity conservation priority sectors that are not formally protected, have an essential part of conservation strategies and goals at global and local scale. Ecological niche modeling is a relevant and important tool for analysis and distribution of species, also is used to determine the biodiversity patterns through the regions. The main objective of this work was to identify the sites with high biodiversity patterns in a sector of Chaco Seco ecoregion that haven't been protected with environmental legislation. Through biodiversity sampling with foot transects, camera traps and interviews, it was registered the presence of large and medium mammals in Santiago del Estero Province. Biodiversity pattern maps were then developed from potential distribution models (SDMs) of 5 mammalian species selected for being relevant for conservation. To define zones that could be characterized like conservation gaps, pattern maps were contrasted with protected areas layers and legal schemes of land use planning and also, protected forest. For the SDM, 171 records were used, 43 for *M. gouazoubira,* 40 for *P. concolor,* 20 for *M. trydactila,* 43 on *P. tajacu* and 25 on *C. wagneri.* Three models were used to make the biodiversity patterns, one of these, Fuzzy union, were used for the subsequent calculation. The total area of high biodiversity increases to 39.486 km^2, which represents the 29% of provincial area. In consequence the 81% remaining represents the conservation gaps areas for that sector of the ecoregion.

Keywords. Chaco Seco ecoregion; Biodiversity; Mammals; Species niche models; Conservation gaps.

INTRODUCTION

One of the most relevant characteristics of biodiversity, is the fact that it doesn't occurs in uniform ways, because of that, the spatial patterns of richness have been an object of study for a long time, in a different scales and focus, like community ecology (Krebs, 1978; Begon *et al.,* 1990), biogeography (Rapoport, 1975; Pielou, 1979; Simberloff, 1983; Murguía, 2005), and most recently from macroecology perspective (Brown, 1995; Gaston *et al.,* 2000), as well as integrating several of them (Magurran, 1988; Rosenzweig, 1995).

Studies of ecological models, like geographic distribution models, aims to estimate the similar condition in every site with conditions in known occurrences locations (and maybe the not occurrence) of a phenomenon, being an extended application in a lot of recents investigations. One of the common ways to use the methodology is to predict the species ranges with climate data as a predictive variable (Hijmans *et al.,* 2017). The focusing on ecology habitat association has been used in a variety of purposes including conservation and ecological management.

In particular, the focusing is being used to develop predictive models to estimate the population size and geographical ranges, and additionally to identificate the potential habitat changes (Stillman & Brown, 1994).

There are diverse modeling techniques (GLM, GAM, GARP, ENFA, Maxent, etc.) that can be used depending on the records (data) available for each species, the climate data and required precision. Some comparisons between different techniques were developed, and although there are no general conclusions, Maxent seems to work better than others (Sosa-Escalante *et al.,* 2013). Maxent

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software (Phillips *et al.,* 2006) is especially popular in species distribution/environmental niches modeling, with more than 1,000 applications published since 2006. The main characteristic is the possibility of creating the model from presence data and environmental variables.

This article provides a geographical approach to establish conservation gaps in the province of Santiago del Estero, an important portion of the Dry Chaco ecoregion. Ecological niche models of large and medium mammals of ≥ 1 kg of body mass (Chiarello, 2000) were used, selecting the species with greater relevance from the perspective of biodiversity conservation within the region, as an analytical tool that determines the potential distribution of those species. In this way, it is possible to obtain different maps of biodiversity richness and link this to the formal strategies for conservation and management of natural resources in the province, such as the forest categories of the OTBN (native forests territorial ordering, by its spanish acronym) of Law No. 6.942 or the sites designated as protected areas by provincial regulations (Law No. 6.381).

MATERIAL AND METHODS

Study Area

The study is located in Santiago del Estero province (Fig. 1), between 25°35′ y los 30°41′S and 61°34′ y los 65°34′O, covered totally by Chaco Seco ecorregion (Cabrera, 1994). The fisonomy of this region is typically represented with quebracho colorado (*Schinopsis lorentzii*) and quebracho blanco (*Aspidosperma quebracho-blanco*) (Morello & Adamoli, 1974), with a mixture of palmares, algarrobales, simbolares, espartillares, pastizales, etc. (Naumann, 2006; TNC *et al.,* 2005). The weather there is semi-arid continental (Cabrera, 1971), warm with dry winters seasons and rainfall in the order of 750 mm annually. Higher temperatures are registered in summer, up to 45°C with the maximum absolute isoterm for Argentina, that is called the Sudamerican Warm Pole (Prohaska, 1959). There are hydric deficits along the year reaching the maximum values in vegetative periods (spring and summer), (Bruchmann, 1981). The plain covers almost the entire province, with limo-loessicos soils (Lorenz, 1995; Moscatelli, 1990).

Nowadays, the Gran Chaco Americano is considered one of the higher priority ecoregion in Latin America and Caribe for conservation, due to the high number of endemism and biodiversity richness of mammals living there (Redford *et al.,* 1990; Mares, 1992; Olson *et al.,* 2001; Ojeda *et al.,* 2002; Torres & Jayat, 2010; Sandoval & Bárquez, 2013). However, the ecosystem has been calificated like "vulnerable" for habitat loss, land cover transformation, habitat fragmentation and low conservation efforts in grasslands, savannahs and forest (Dinerstein *et al.,* 1995).

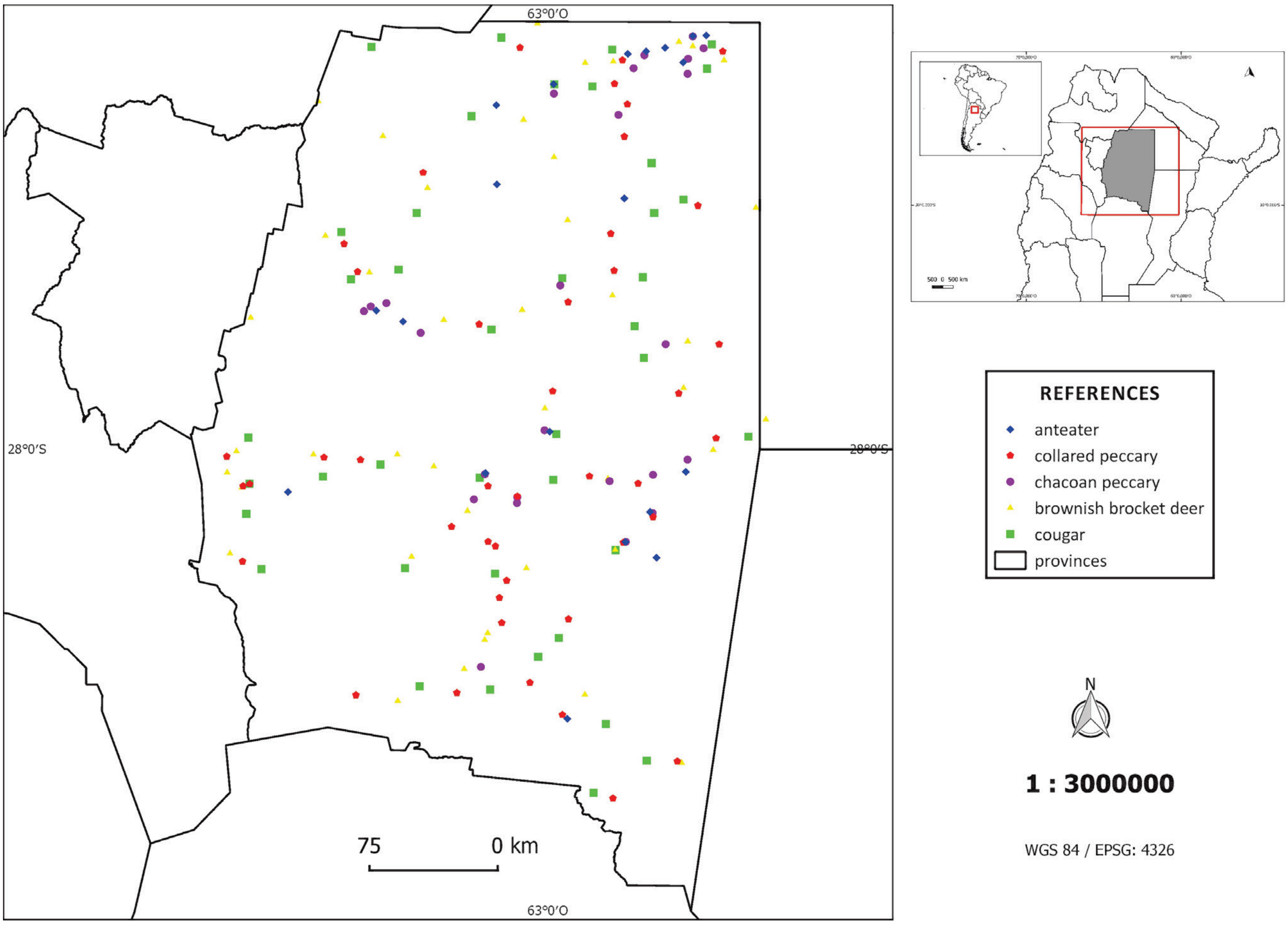

Figure 1. Study area. Geometric figures of different colors indicating the sites of presence of the selected mammalian species used for the distribution models.

Ecological niche modeling

Five species of large mammals were selected a priori, being these *Catagonus wagneri* (Rusconi, 1930), *Mazama gouazoubira* (Fischer, 1814), *Pecari tajacu* (Linnaeus, 1758), *Myrmecophaga trydactila* (Linnaeus, 1758) y *Puma concolor* (Linnaeus, 1771), which have a relevant importance from a conservation perspective for having a decline population, some of them are categorized like "vulnerable" or "in danger of extinction" (Chebez *et al.,* 2011) (Annex 3: with population status). Also, presence of these species is considered an indicator of ecosystem stability, optimal habitat conditions and presence of another species (Muzzachiodi & Sabattini, 2002). Finally, and focusing on methodology requirements, they reach the minimum number of sites necessary to run the model (Merow *et al.,* 2013).

To obtain the distribution maps, it was modeled using the Maxent learning machine algorithm (software Maxent 3.4) (Phillips *et al.,* 2006), due to only having presence data. Maxent takes a location list with presence data, almost called only presence data (OP), as well as a group of environmental predictions (for instance, precipitation, temperature) through a user-defined landscape that divides it in grid cells (Merow *et al.,* 2013). From this way, Maxent takes a sample of locations and then, is contrasted with OP. Presence is known in background places. Maxent generates a probabilistic distribution of grid pixels beginning from uniform distribution raising the data fit repeatedly.

A total of 171 records were employed, 43 for *M. gouazoubira,* 40 for *P. concolor,* 20 for *M. trydactila,* 43 in *P. tajacu* y 25 of *C. wagneri.* These were generated from sampling in different places and ecosystems almost coincident with protected areas and biological corridors in Santiago del Estero without a previous sample design, from 2006 until the present. Linear transects from 2 to 8 km of variable longitude (Stephens *et al.,* 2006), with a distance between them not less than 2 km; and semi structured interviews to rural communities, only selected those of high reliability (Giraudo & Abramsom, 1998; Bolkovic, 1999), were employed to take the data in situ. For the second point, the ability of the interviewed to correctly identify the species was evaluated, by discriminating between species (Rabinowitz, 1997) in field guides and photography material (Canevari & Vaccaro, 2007). Also, abundance and population data were taken too. Thirdly, camera traps were used: Automatic cameras (brands: Tasco of 5 mpx and Trail camera from 12 mpx) above tree barks at 50 cm from the floor, near animal tracks. These cameras were located not less than 1,5 km (Trolle & Kéry, 2003). Six cameras with activation turns and checking every 60 days were employed.

The prediction covariables are the 19 Worldclim bioclimatic variables for actual conditions (~1960-1990) 1.4 version (Hijmans *et al.,* 2006; (worldclim)) with a spatial resolution of 30 arcseconds that represents 33 and 43 zones of planisphere grid, being a 30 × 30 grades mosaic. From the altitude layer and using QGIS software (versión 2.18.15) the topographic variable was created. A categorical variable that refers to land cover was incorporated, which has 20 different types of land covering (Tateishi *et al.,* 2011, 2014). The modeling was made in two successive stages, firstly to determine the most relevant variables and the last one to select a binary map of high AUC. In both stages, a cross validation was used (Stockwell, 1992) with a partitioned sample of 5 fold of equal size. The cut-off threshold "maximum training sensitivity plus specificity" was set for the binary output. Highly correlated covariates were dismissed (Spearman test) and finally, those with a high perceptual contribution were chosen. To determine that contribution, at each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda is negative. The bias file was created using the Kernel density function to reduce the spatial autocorrelation error and therefore the lack of independence of the species' record sites. In addition, duplicated records or with a less distance of 5 km were left.

Spatial Biodiversity

The works of Pearman & Weber (2007) and Koleff *et al.* (2008) were considered, who establish that spatial patterns of species richness are determined by common species primary, according to coarse resolution studies, and suggest that spatial patterns in species richness could be described through sampling of widely distributed species. From set up a map (logistic output) of potential distribution of five species previously considered and employing two programs, Qgis geographic information system (2.18 version) and Prion (0.11 version) (Vergílio *et al.,* 2016), three synthesis maps or consensus models were created with species richness patterns for Santiago del Estero province following general guidelines (Ceballos *et al.,* 1998; Rahbek, 2005). For this purpose, three algorithms were used: the "Fuzzy union" geoalgorithm and the "max (a, b)" operator of the SAGA interface, the "Total Beta" and "Richness of species" of Prion, being the input parameters by default 5 probabilistic scenarios, with 100 generations, a crossover rate of 90%, a mutation rate of 50%, 20 targets and a cost value of 10.

To determine the conservation gaps sites, high ranked sectors in the species patterns scales of "Fuzzy union" geo algorithm were considered, this is those included in graphic scale of reference between values of 0,75 and 1 (orange to red in Fig. 8) or which we define as "high biodiversity sites" (HBS). This algorithm was selected because it presents a more conservative spatial development, being on an intermediate point between "Beta total" and "Richness species".

In order to visualize only the HBS geographically (Fig. 9), and the necessary calculations for Table 2, we effectuated cartographic subtractions between "Fuzzy union" and a vector layer that contains the category I, OTBN corridors and protected areas (administered by Dirección de Bosques y Fauna de Santiago del Estero) adding the polygon of Copo National Park (APN & SIB, 2022). For this, the algorithm *clip raster with polygon* of SAGA interphase and *r.report* of Grass interphase on Qgis, were used.

RESULTS

Potential distribution of mammal's species selected

The area of potential distribution for the 5 species selected previously for Santiago del Estero are 49.721 km² for cougar (Fig. 2B) representing 36% of provincial territory being moreover the largest extension. The second is the anteater with 44.371 km² (Fig. 2E) equivalent to 32% of the territory. The model of brown brocket deer presents an extension of 38.662 km² (Fig. 2C) equal to 28% of the province. Finally, the peccary distribution was 27.088 km² for collared peccary (Fig. 2D) and 23.517 km² for chacoan peccary (Fig. 2A), representing 19% and 17% of the province respectively.

Most important variables on the mammal modeling

Table 1 shows a prevalence of "environment" variable in the models with high AUC selected (section 2.2), where 3 of the 5 species (60%) presents the highest percent of contribution to determine potential distribution or habitat aptitude. If we consider absolute participation covariables frequencies in the selected models, "environment" has an n = 5, being the only one always present in all models. It follows by "altitude" with n = 2, while the rest of covariables only appears once on the models.

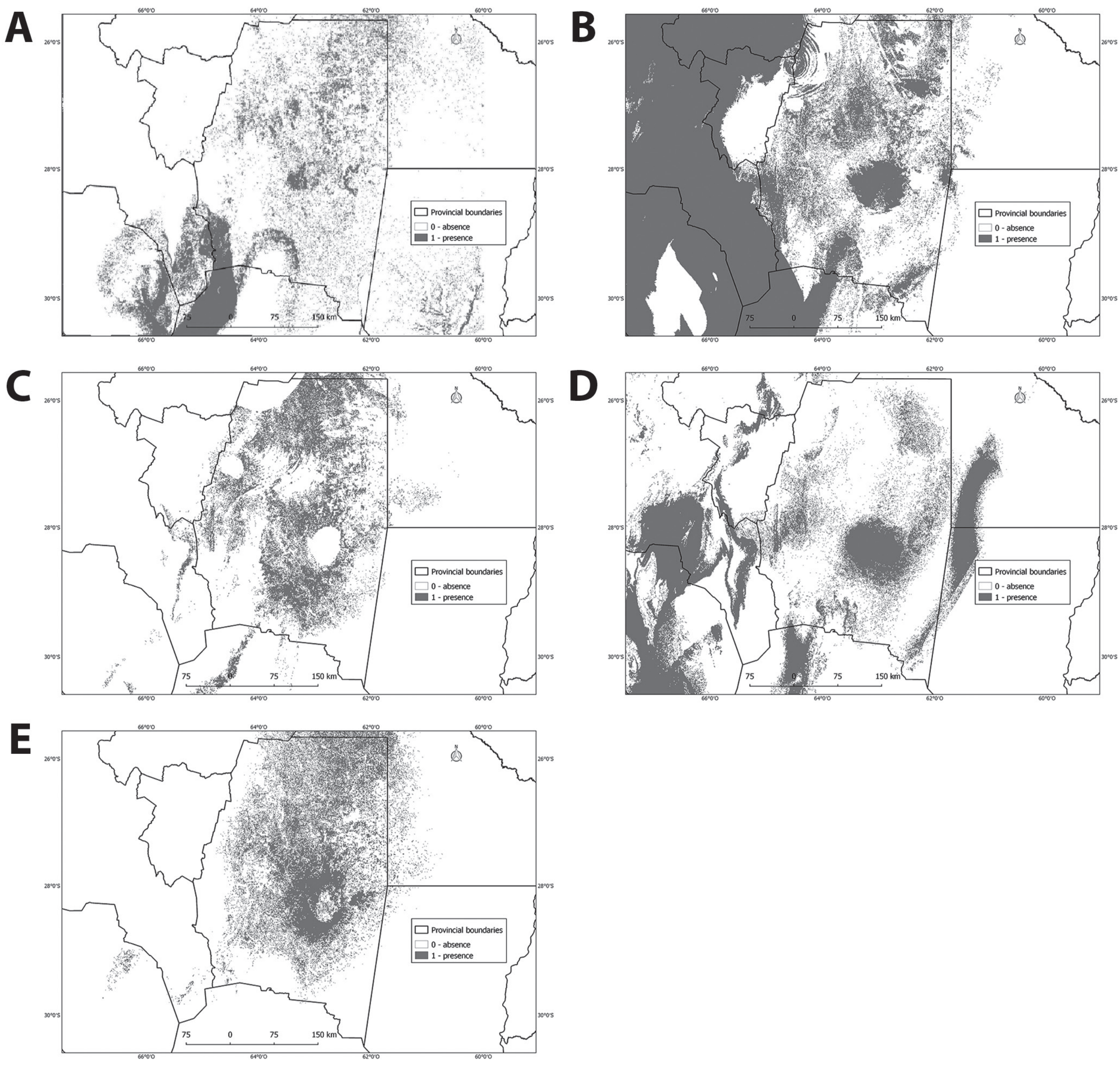

Figure 2. Binary maps of potential distribution of (A) chacoan peccary, (B) cougar, (C) brown brocket deer, (D) collared peccary and (E) anteater. The gray pixels indicate the places of presence of the species.

Table 1. The percentages of the predictor variable with the greatest contribution to the distribution models selected for each species are displayed.

Species	Predictor covariate	Percentage
Cougar	environments	27,40%
Collared peccary	environments	26,60%
Chacoan peccary	environments	65,20%
Brown brocket deer	Average temperature of the three driest months (bio 9)	28,60%
Giant anteater	Maximum temperature of the warmest month (bio 5)	52,30%

A detailed analysis of the relationship between predicted variables and species habitat suitability is presented at Figs. 3-7.

The three more relevant variables in the model development of cougar were environment, altitude and precipitation of the dampest month (Figs. 3A-3C). The model predicts a maximum aptitude of habitat for forestry ecosystems, from 700 meters above the sea level with precipitation of approximately 90 mm for the dampest month.

In the brown brocket deer model, the main variables were media temperature of most dry trimesters, the diurnal range of media temperature and environment (Figs. 4A-4C). The projected model settled the highest habitat aptitude around 12°C the driest quarter average, with a range of medium diurnal temperature above 15°C and in a variety of forestry or bushlands environments and mosaic patches with any grade of anthropic modification.

The variables with the greatest contribution to the chacoan peccary were the different types of environments, the warmest trimester rainfall and territorial slope (Figs. 5A-5C).

The better habitat suitability is given by forest, savannah and wetland ecosystems. Rainfall range should be between 250 to 300 mm and the slopes up to 10%.

The anteater model shows as main variables the maximum temperature of the warmest month, environments and temperature seasonality (Figs. 6A-6C). The model displays the maximum habitat aptitude for temperatures up to 40°C, savannah ecosystems and a maximum value of 60 on standard deviation of temperature seasonality.

The three more relevant variables on the development of collared peccary model were environments, altitude and annual temperature range (Figs. 7A-7C). This model presents the high habitat aptitude to forestry ecosystems and grassland matrix with scattered and brush trees; up to 800 meters with 30°C annual temperature variation range.

Species richness patterns in Santiago del Estero

Maximum classification sectors in spatial patterns of species richness scales, which is those included in the scale between 0,75 and 1 values (orange and red colors in Fig. 4), shows the highest agreement with forestry ecosystems of Santiago del Estero. The algorithm that gives the largest area to the highest levels of species richness is "total beta" (Fig. 4C) with 106.985 km^2, followed by "fuzzy union" (Fig. 4A) with 39.486 km^2 and the one that gives the least area to these levels is "species richness" (Fig. 4B) with 20.553 km^2. Some discrepancies between those models are the fact that only "fuzzy union" (Fig. 4A) detected a HSB sector among Salinas de Ambargasta and Catamarca province, whereas "beta total" and "species richness" didn't recognize that.

Conservation gaps in Santiago del Estero

With the purpose of comparing the overlap of HBS with OTBN, biological corridors and protected provincial areas, "fuzzy Union" algorithm was selected (Fig. 4A).

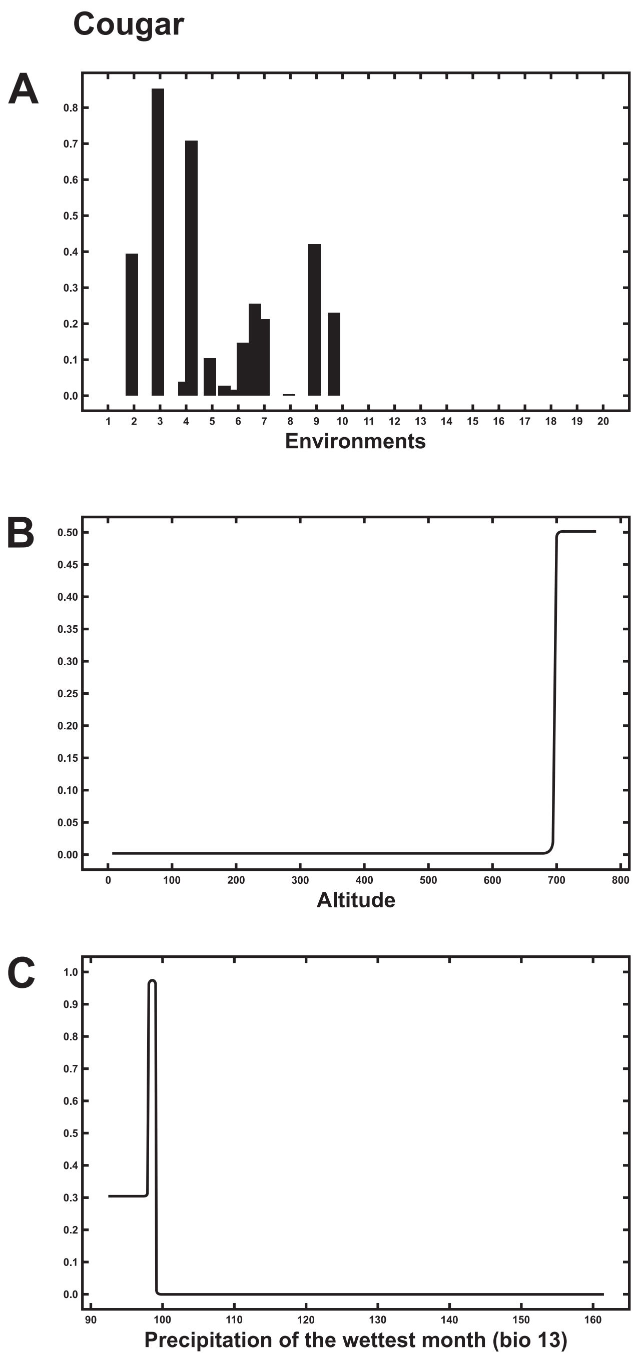

Figure 3. Response graphs of habitat suitability (ordinate axis) according to the explanatory variables that intervened in the adjustment of the model for cougar (A, B, C). Precipitation is expressed in mm and altitude in meters. Source of bioclimatic variables (bio), site https://www.worldclim.org/data/bioclim.html.

The total HBS surface is 39.486 km² (Table 2) that represents 29% of provincial territory. This area is comparable with the surface of significant biodiversity areas map of TNC *et al.* (2005). Total protected areas surface, biological corridors and I OTBN category included the overload sector hides to 27.549 km², 19% of them, that means 9.400 km² belong to HBS places (Table 2). Consequently, the remaining 81%, equivalent to 31.900 km² and representing the largest proportion of the HBS territory, are not under any formal protection system equivalent to protected area management categories I to III of the IUCN system. Even so, this territory takes part of category II or yellow color of OTBN, which confers a certain degree of shelter to forest ecosystems and would be comparable to IUCN Categories V or VI.

On the other hand, when the comparison is intrinsically related to the HBS surface that every class considered in Table 2 has, we found that there are not significant differences between them. From this observation, it could be inferred that HBS surfaces from OTBN category I, corridors and also, protected areas are not high. However, the low proportion of percentage detected between protected areas and category I – corridors, might be related to big surfaces of salines and

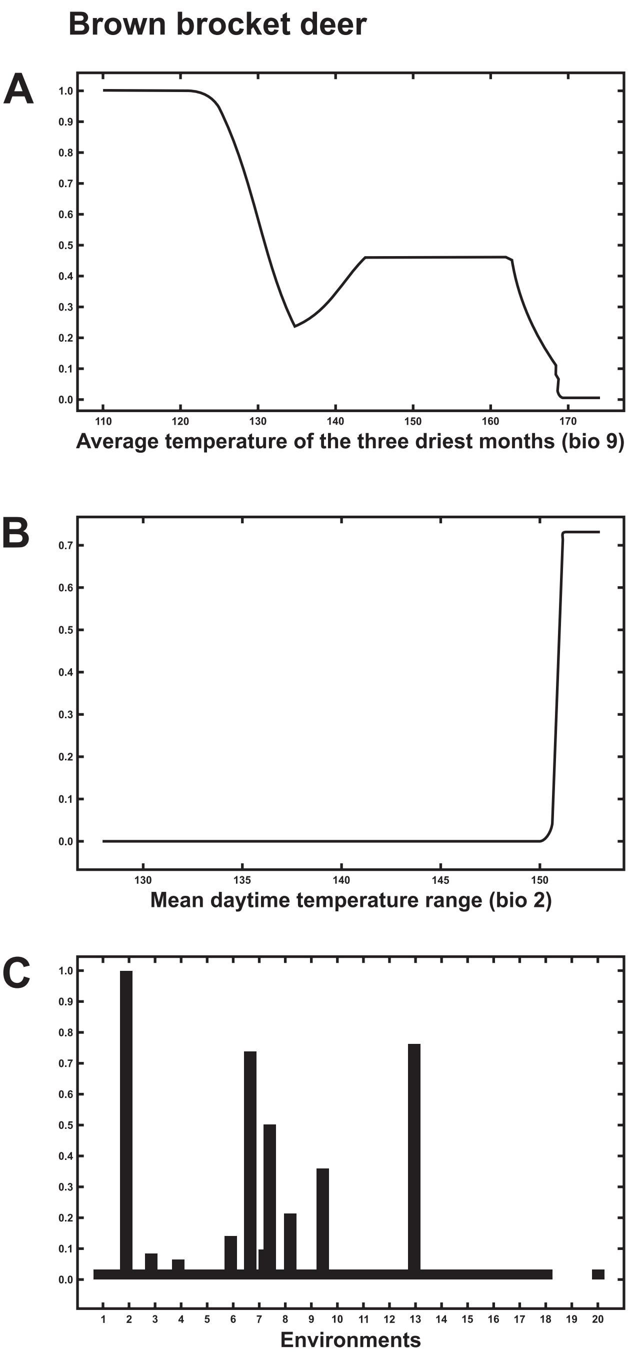

Figure 4. Response graphs of habitat suitability (ordinate axis) according to the explanatory variables that intervened in the adjustment of the model for brown brocket deer (A, B, C). The temperature is expressed in degrees Celsius. Source of bioclimatic variables (bio), site https://www.worldclim.org/data/bioclim.html.

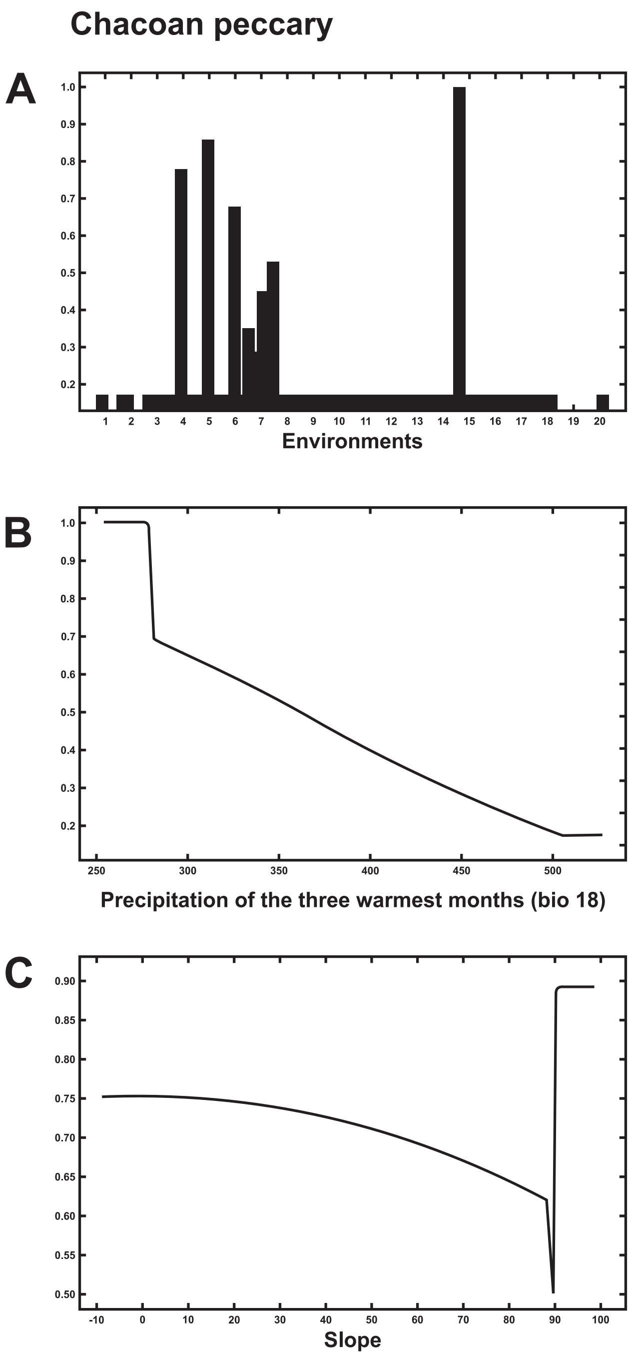

Figure 5. Response graphs of habitat suitability (ordinate axis) according to the explanatory variables that intervened in the adjustment of the model for the chacoan peccary (A, B, C). The precipitation is expressed in mm, the slope in percentage. Source of bioclimatic variables (bio), site https://www.worldclim.org/data/bioclim.html.

wetlands environments between Salinas de Ambargasta and Lagunas Saladas, which are not optimum habitats of none of 5 mammals species considered initially, even though those species occasionally use these environments.

When analyzing the percentages shown in Fig. 10, in particular the 18% corresponding to HBS (Range 0,75 and 1) and comparing them individually against each of the management categories considered in Table 2, we find a wide gap in the percentage of protection of these environments, being the biological corridors the closest with 10%.

DISCUSSION

Individual models of potential distribution

The cougar (*Puma concolor*) is the second largest feline in the Americas after the jaguar (*Panthera onca*), with a wide distribution ranging from North America to southern South America, in Argentine and Chilean Patagonia (Currier, 1983; Shaw *et al.,* 2007). Its large distribution is largely due to being a "plastic" species that can adapt to more disturbed environments such as productive and higher human density (Haines, 2006; De Angelo *et al.,*

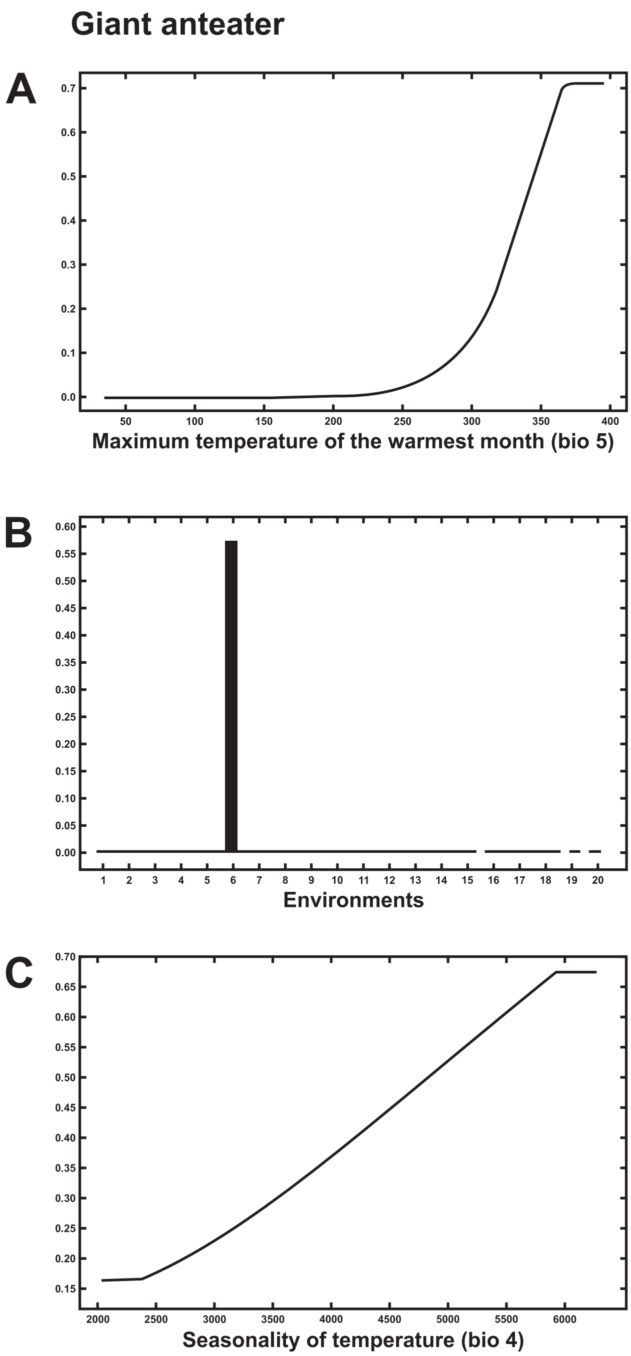

Figure 6. Response graphs of habitat suitability (ordinate axis) according to the explanatory variables that intervened in the adjustment of the model for the giant anteater (A, B, C). The temperature is expressed in degrees Celsius. Source of bioclimatic variables (bio), site https://www.worldclim.org/data/bioclim.html.

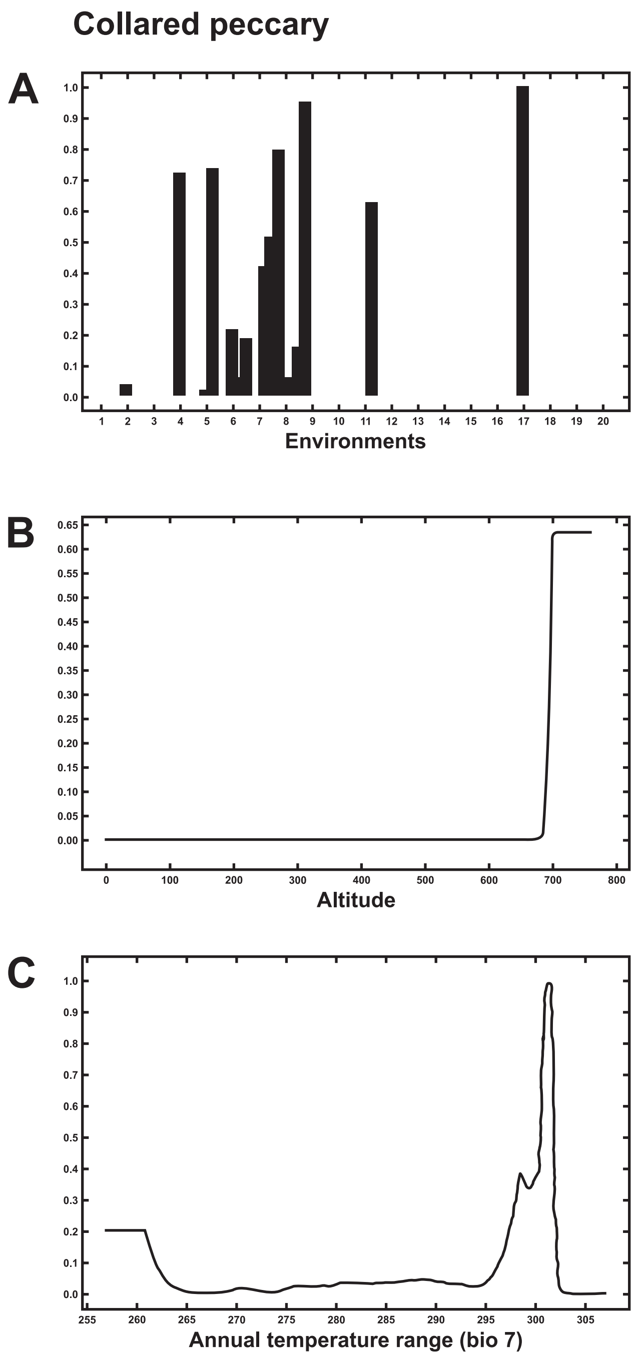

Figure 7. Response graphs of habitat suitability (ordinate axis) according to the explanatory variables that intervened in the adjustment of the model for collared peccary (A, B, C). Temperature is expressed in degrees Celsius and altitude in meters. Source of bioclimatic variables (bio), site https://www.worldclim.org/data/bioclim.html.

Table 2. Surface overlap and proportion of the OTBN and protected areas in relation to sites of high biodiversity (HBS).

Relationship of high biodiversity sites (HBS) with the provincial OTBN and protected areas			
	Total area (km²)	Surface and % of HBS inside (1), (2) and (3)	% with respect to the total HBS area
HBS (Range 0.75 to 1) Fig. 4a	**39.486**	—	—
Protected areas (1)	9.997	2.178 (22%)	5,5%
Category I (OTBN) (2)	9.811	3.034 (31%)	7,6%
Biological corridors (OTBN) (3)	17.292	4.201 (24%)	10,6%

2011). The map of potential distribution of the species presented in Fig. 8B agrees with the record sites for the Dry Chaco ecoregion (Quiroga, 2013; Quiroga *et al.,* 2016) and with the map prepared by IUCN (2015). Even so, it presents marked underestimates for the humid Chaco and overestimation in the region of the Salinas Grandes.

The brown brocket deer (*Mazama gouazoubira*) is a small, solitary cervid widely distributed in South America (Black-Décima, 2000). It is found east of the dry pre-Andean regions in Argentina and Bolivia, extending to the Atlantic coast in the west; its northern boundary is the southern part of the Amazon region, and its southern boundary includes Uruguay and the province of Entre Ríos in Argentina. Although some authors report its distribution throughout Brazil (Eisenberg & Redford, 1999; Grubb, 2005), the most recent evidence indicates its replacement by *M. nemorivaga* in the Amazon region (Duarte, 1996; Duarte & Jorge, 1998; Rossi, 2000). Despite being linked to a wide range of forest ecosystems, they prefer drier and more open environments (Eisenberg & Redford, 1999). In relation to the range of distribution of *M. gouazoubira* presented by Black-Décima *et al.* (2010) and IUCN (2008), we can mention that the biggest difference found in our model is the confinement of the distribution of the species to the Ecoregion of the Dry Chaco (Fig. 8C), not presenting presence in adjacent ecoregions, which should be interpreted as a marked underestimation.

The collared peccary (*Pecari tajacu*) is widely distributed. It occurs in Arizona, New Mexico and Texas in the United States, a large part of Mexico and Central America, the entire Amazon basin, the Pacific coastal forest of Colombia, Ecuador and Peru, the plains and lowland forests of Venezuela, the Guianas and Suriname, all of Brazil, where it is increasingly fragmented in the south and east, and the Gran Chaco of Paraguay, Bolivia and northern Argentina, where it is also found in the upper basins of the Paraná and Paraguay rivers. In Argentina, the species has become extinct in the eastern and southern portions of its original distribution. The Argentine population of collared peccaries in Misiones is isolated from the rest of the country (Gongora *et al.,* 2011). The model shown in Fig. 8D shows a fragmented geographical distribution of the collared peccary, differing significantly with the works of Camino (2016), Altrichter & Boaglio (2004) and Altrichter (2005), for the sector of the provinces of Chaco and Formosa, in which our model does not indicate optimal habitat quality for the species, which in light of the evidence of presence recorded by other researchers demonstrates a bias in the estimate. Even so, the model is accurate in relation to the forest environments of the province of Santiago del Estero. It is interesting that some sectors of local low-altitude mountain ranges such as Sierras de Guasayán show environmental aptitude for the species while Sierras de Ambargasta and Sumampa do not.

The large anteater (*Myrmecophaga tridactyla*), is the largest species of anteater in the world and is widely distributed in Central and South America, but despite this it is extinct in many areas of its original distribution (Collevatti *et al.,* 2007). This terrestrial anteater is found in humid tropical forests, dry forests, savannah habitats and open grasslands; It has also been recorded in the Gran Chaco (Meritt Jr., 2008; Noss *et al.,* 2008) and timber plantations (Kreutz *et al.,* 2012). According to Superina

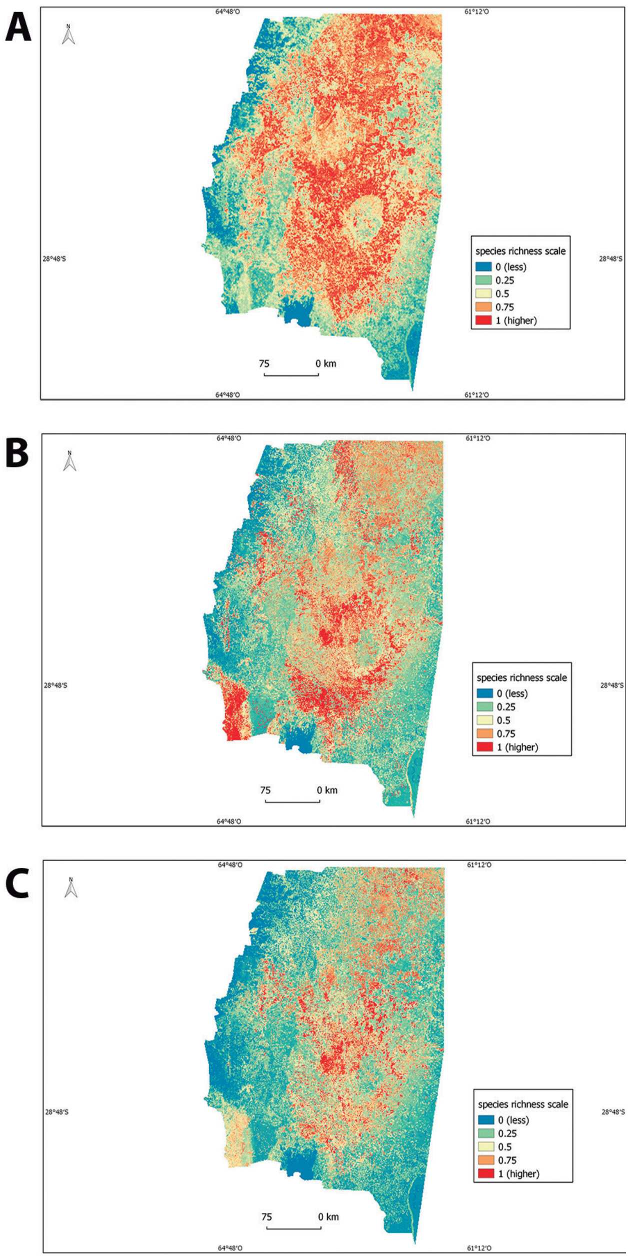

Figure 8. Species richness maps obtained using three algorithms, (A) "fuzzy union", (B) "species richness" and (C) "total beta".

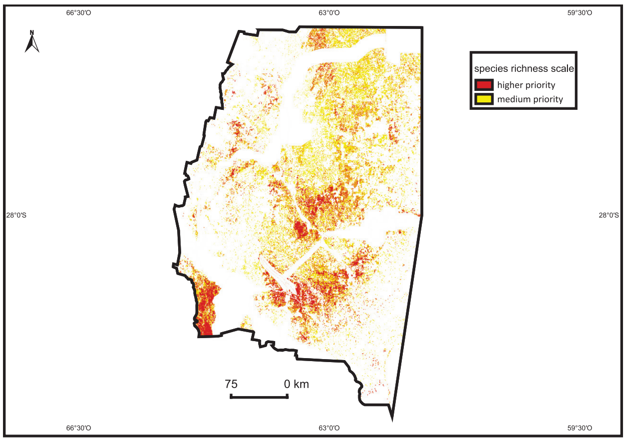

Figure 9. Conservation gaps in Santiago del Estero. The shade of red highlights the theoretical sites of highest priority for conservation.

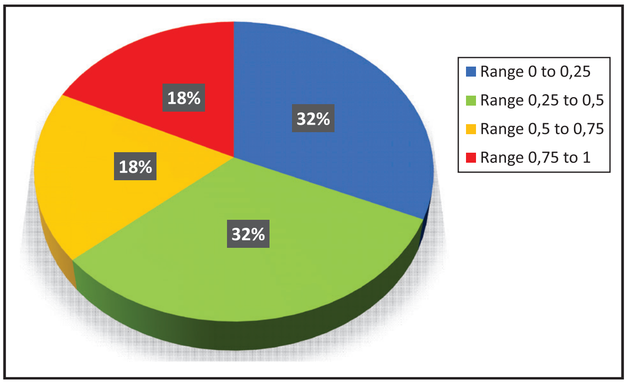

Figure 10. Percentages with the proportions of species richness range surfaces in the model generated by the "fuzzy union" geoalgorithm.

& Loughry (2012) the extent of presence in Argentina has decreased by 45% in the last 40 years, mainly due to poaching, fragmentation and habitat destruction, fires and traffic accidents (Cáceres *et al.,* 2010; Lacerda *et al.,* 2009). We find recent records of the presence of anteater in sectors of the center and south of Santiago del Estero, which differs from the southern limit of distribution proposed in other works (Da Fonseca & Aguiar, 2004; Pérez-Jimeno & Llarín Amaya, 2009) which stipulated it around 27°S. On the contrary, the model presented (Fig. 8E) agrees with the comments made by Parera (2002) mentioning a historical distribution with a southern limit close to 31°S. Therefore, we infer that there are still remnant populations in those latitudes, although highly fragmented and decreased in population density, placing them on the verge of local extinctions.

For this part, a detailed analysis of the distribution model of the chacoan peccary (*Catagonus Wagneri*) (Fig. 8A) is presented in Rivas *et al.* (2021). Even so, if we compare it to the four remaining distribution models, it showed a distribution where it not only occupies forest ecosystems with a higher tree stratum such as the "Bosques y Arbustales del Centro" complex, but also environments with less tree cover such as the "Llanos y Valles Interserranos" complex. In addition, there could be an overestimation with respect to the large area occupied in the Salinas Grandes complex, an ecosystem that in large sectors would lack minimum conditions for the subsistence of the species. In relation to this last type of environment, although in principle it is not consistent with the typical habitat condition described for it (Sowls, 1984), we must emphasize that in large portions of the Dry Chaco there are vast systems of wetlands or wetlands such as those of the Río Dulce in Santiago del Estero and river mouth of the Mar Chiquita lagoon, in which there are also records that can support the presence of the species.

For both species of peccaries this significant link between types of environments or ecosystems and the presence and/or abundance of them was already indicated in previous works (Sowls, 1984; McCoy-Colton *et al.,* 1990; Taber *et al.,* 1994; Altrichter & Boaglio, 2004; Camino, 2016).

Because the study aimed to estimate distributions at the local level, we considered that the underestimates mentioned in the geographical range of the models could respond to the parameterization established in maxent, in particular the Regularization multiplier (betamultiplier), which was established in 0.1. This value restricts predictions around points of presence as mentioned in other papers (Hastie *et al.,* 2009; Merow *et al.,* 2013).

Species richness patterns and conservation gaps

If we compare the three models of species richness in Fig. 4, we notice in general a geographical concordance in the selection of the sites with the greatest species richness, coinciding largely with the sectors of remaining forest ecosystems in the province, in particular the quebracho forests and mixed forests described by various authors (Morello & Adamoli, 1974; Brassiolo, 1997). In the same sense, the sectors with lower levels of species richness agree with those regions of the province most disturbed by the change in land use as a result of the advance of the agricultural frontier, such as the areas bordering the provinces of Chaco, Santa Fé and Tucumán. This aspect that links the reduction of biodiversity because of anthropic impacts in the Chaco ecoregion was pointed out in the works of Torrella & Adámoli (2005) as well as in Vallejos *et al.* (2017), among others.

We also compared the models in Fig. 4, the HBS sectors, with other works such as the ecoregional evaluation of the Gran Chaco Americano (TNC *et al.,* 2005), which determined priority areas for conservation based on the distribution of the main vertebrate groups. Based on this, if we focus only on the mammalian taxon, we see that the TNC map presents undemarcated localities or biases in relation to our own models (Fig. 4).

Punctually we notice large sectors not considered by TNC such as the Sierras de Guasayán, most of the departments Copo and Alberdi and the Lagunas Saladas of the J.F. Ibarra Department. Both approaches coincide in the underestimation of the Sierras de Sumampa y Ambargasta. On the contrary, if we consider the map of significant areas for biodiversity of TNC *et al.* (2005), which is a synthesis or consensus map of all the others elaborated in this work, we see a high degree of agreement with respect to our own models (Fig. 4). If we compare these results with the publication of Nori *et al.* (2016), which had as one of its objectives to determine priority conservation areas for endemic vertebrates; we see that this work does not identify conservation areas throughout the provincial territory of Santiago del Estero, except for two very small sectors to the north and south, coinciding with the conservation area of Copo and with a small sector of the Río Dulce wetlands. This shows a clear discrepancy with the results presented in this work (Fig. 4), from which large sectors are observed on the central strip of the provincial territory as potential priority environments for conservation.

On the other hand, we must emphasize that the models developed by the three algorithms (Fig. 4A, B, C) present underestimates in specific areas such as Sierras de Sumampa, Salinas de Ambargasta and sectors of the Pellegrini department such as Río Horcones and Cerro Remate. These biases in prediction may be attributable to an incomplete sample design at the provincial scale, which is then translated into species distribution models. Another factor to consider is the selection of a small group of species and belonging to a single taxonomic group of vertebrates, as for example in the work of Arzamendia & Giraudo (2004), which means that certain habitats are not so represented in the final process of assembling the map of biodiversity patterns. In this aspect, it is pointed out that only mammal species from terrestrial environments were considered, so it was to be expected that those representative sites of rivers and wetlands would be underestimated.

However, given the limitations of the present work, this result does not imply that protected areas with extreme environments such as those mentioned above, such as large salt flats or areas of low mountain ranges; do not contribute to the conservation of biodiversity, especially when we refer to the protection of endemic, rare or relict species typical of these places and very well adapted to adverse conditions for most of the representative individuals of this ecoregion (Coirini *et al.,* 2010; Curto, 2009), in addition to being one of the areas with the least physiognomic transformations due to the characteristics of developing in soils with extreme conditions of salinity and aridity (Giménez *et al.,* 2008).

If we consider the persistence over time of the 31,900 km² mentioned in the section 3.4 without strict protection, presenting healthy ecosystems even prior to the promulgation of the National Law of Native Forests, we agree with Abt (2015), Guzmán (2017), and Domínguez (2012) that such conservation responds to the permanence in the territory of traditional life and production systems of low environmental impact in territories in charge of peasant settlers, which gives value and reinforces the identity of peasant communities in their right to land, sustainable use and protection of native forests (Jara, 2014).

As we discussed in the presentation of this article, the modeling and estimation of the potential distribution of representative mammals of the region, allow optimizing conservation tasks, the determination of those new sites destined for protected areas or some category of protection. Particularly, this study reveals valuable information to take into account in the light of future updates of territorial planning (Gautreau *et al.,* 2014) since historically it was done in function of productive activities favoring forest and agricultural production and management, without taking into account the ecological potential, connectivity, complexity and all the actors associated with the different existing areas within the province (Collazo *et al.,* 2013; Gautreau *et al.,* 2014).

CONCLUSIONS

From the previous analyses it is shown that large sectors of natural ecosystems and fauna habitats of importance for conservation in the Chaco Seco ecoregion were not considered in the spatial designs of the current management and protection systems of nature, raising the need for periodic reviews or updates that attend to the dynamics of distribution and change of these areas, according to what was proposed by Castaño-Villa (2005) and the necessary flexibility in the face of new scenarios imposed by climate change.

The proportion of HBS excluded from a type of strict protection (protected area or category I of the OTBN) is shown. That sector could host biodiversity and to which special attention should be paid when managing the territory and allocating the productive uses to which they can be subjected, so as not to lose the ability to host species such as those presented in this work and the general functionality of the ecosystems in terms of the provision of goods and services.

The magnitude of the territorial extension of the HBS means that the establishment of more protected areas as a conservation strategy could be unfeasible from economic, political, and social aspects, so it would be necessary to develop new models of management of landscapes and ecosystems, which contemplate and incorporate as priorities the traditional systems of life and production of peasant and indigenous inhabitants.

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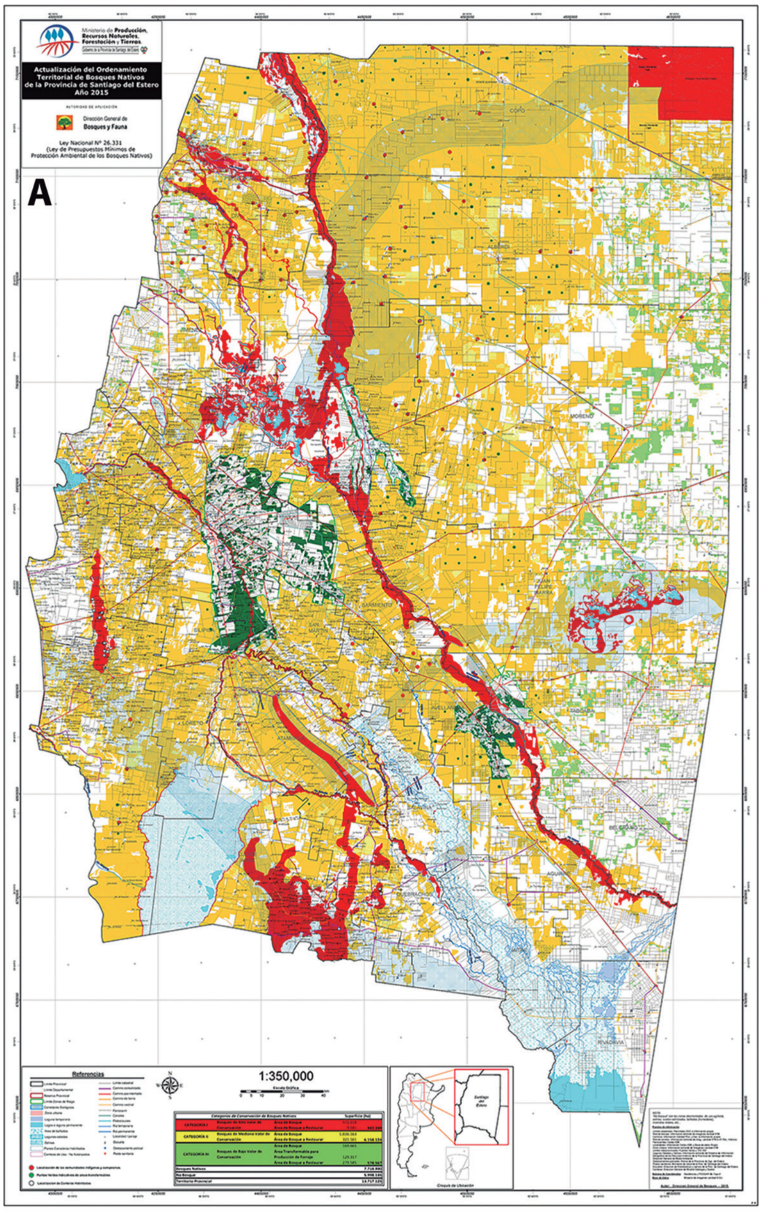
APPENDICES

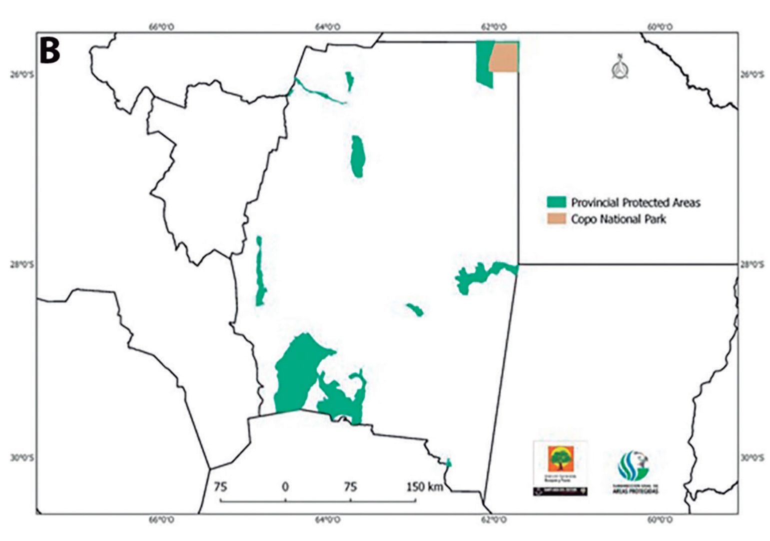
Annex 1

Camera trap pictures: collared peccary (A), cougar (B), brown brocket deer (C) y anteater (D).

Annex 2

Maps. (A) OTBN of the National Law of Native Forests and (B) Protected Areas of Santiago del Estero; Supplied by the Dirección de Bosques y Fauna of the government of Santiago del Estero which states that of the areas on the map only the Park and Reserve Copo have formal limits.





Annex 3

With the status or conservation categories of the mammal species analyzed in the work. Species categories: EN: Endangered; NT: Near Threatened; VU: Vulnerable; LC: least concern; DD: Data Deficient. Source: 2019 categorization of mammals in Argentina according to their risk of extinction. Red List of mammals in Argentina. Digital version: https://cma.sarem.org.ar. (*) The genera Parachoerus and Catagonus appear as synonyms on the official SAREM site.

Species		National status	International status (UICN)
Scientific name	**Common name**		
MYRMECOPHAGIDAE family			
Myrmecophaga tridactyla	Giant anteater	VU (Vulnerable)	VU (Vulnerable)
FELIDAE family			
Puma concolor	Cougar	LC (Least concern)	LC (Least concern)
TAYASSUIDAE family			
Parachoerus wagneri (*)	Chacoan peccary	EN (Endangered)	EN (Endangered)
Pecari tajacu	Collared peccary	VU (Vulnerable)	LC (Least concern)
CERVIDAE family			
Mazama gouazoubira	Brown brocket deer	LC (Least concern)	LC (Least concern)

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