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Distribution of extant xenarthrans (Mammalia: Xenarthra) in Argentina using species distribution models

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Abstract

The xenarthrans are the only group of mammals that originated in South America; there are 31 living species: six sloths, four anteaters, and 21 armadillos. In Argentina, 18 species of xenarthrans were cited. The objectives of this study were to compile the existing information on the distribution of the xenarthrans of Argentina, to use species distribution models to map the potential distribution of these species, and to assess patterns of species richness of this important group of mammals. We obtained a total of 975 records corresponding to 706 different collecting localities from Argentina. We generated species distribution models for 15 of the 18 species present in the country. Virtually all of Argentina is occupied by xenarthrans. The highest richness of species is in the north and northeast of the country in the humid and arid Chaco, probably in relation with the mosaic of ecosystems recorded in these regions. These ecoregions have different degrees of habitat degradation and continues to be a major threat for the viability of the xenarthrans occurring there. The information given in this contribution is an input to clarify occurrence and distribution of this group of mammals.

Keywords: anteaters; armadillos; sloths; South America.

Introduction

The xenarthrans are presumably the only group of mammals that originated in South America (Vizcaíno and Loughry 2008), and almost all extant species are found within specific regions of Latin America (Aguiar and Fonseca 2008, Abba and Superina 2010). Only one species, the nine-banded armadillo (*Dasypus novemcinctus*), has successfully colonized much of the southern United States in the last 200 years (Taulman and Robbins 1996). According to a recent synopsis (Gardner 2007), there are 31 living species of xenarthrans: six sloths, four anteaters, and 21 armadillos. However, these species represent a small fragment of a much more diverse fossil assemblage that includes such well-known oddities as the giant ground sloth and glyptodonts (MacKenna and Bell 1997). Current molecular evidence indicates that the Xenarthra represents one of the four major clades of placental mammals, and potentially a basal offshoot of the founders of the eutherian line (Delsuc and Douzery 2008), highlighting the phylogenetic importance of the group.

The global conservation status of xenarthrans places them among the mammals most at risk of extinction (Schipper et al. 2008). However, this group has not received the same attention as other more charismatic orders. In Argentina in particular, the conservation assessment of xenarthrans is characterized by a lack of knowledge, synthesized by the impossibility of determining the conservation status of six of the 18 species ever cited for Argentina (Superina et al. in press). Of the remaining species, eight are in a threatened (Critically Endangered, Endangered, Vulnerable) or near threatened category, and only four species have a conservation status of low risk with some caveat (Superina et al. in press).

The objectives of this study were to compile the existing information on the distribution of the xenarthrans of Argentina, to use species distribution models (SDMs) to map the potential distribution of these species, and to assess patterns of species richness of this group of mammals.

Materials and methods

Data

During the lapse 2005–2007, we collected point locality data for each species from natural history museum collections, published literature, and our own field work. Geographic coordinates were assigned to every record, using national and international gazetteers (e.g., Geographic Military Institute of Argentina, NIMA-GeoNET Names Server). We obtained 19 bioclimatic variables from the WorldClim database (http://www.worldclim.org; Hijmans et al. 2005), each at a resolution of 2.5 arc-minutes (ca. 21.62 km^2 at the equator). These variables are derived from temperature and precipitation data for the period 1950–2000. Additionally, we derived slope

and aspect from elevation data. All 22 layers were clipped to include the entire boundary of Argentina. The variables used in the analysis were elevation, aspect, annual mean temperature, mean temperature of warmest quarter, mean temperature of coldest quarter, annual precipitation, precipitation of wettest month, precipitation of driest month, precipitation seasonality-coefficient of variation, precipitation of wettest quarter, precipitation of driest quarter, precipitation of warmest quarter, precipitation of coldest quarter, mean diurnal range [mean of monthly (max. temp - min. temp)] isothermality, temperature seasonality, maximum temperature of warmest month, minimum temperature of coldest month, temperature annual range, mean temperature of wettest quarter, and mean temperature of driest quarter and slope.

We used a digital map of the ecoregions of Argentina from the Argentine Secretary for the Environment (Figure 1; Burkart et al. 1999).

Because many specimens from museum collections were collected several decades ago, changes in land cover that may have occurred since then must be taken into account. For that purpose, we used the Global Land Coverage dataset (GLC 2000, see Eva et al. 2004) to restrict the species distribution maps obtained from the SDMs. The classes that were excluded were intensive agriculture, mosaic agriculture/degraded vegetation, mosaic agriculture/degraded forests, barren/bare soil, and deserts. Given that not all species are affected in the same way by the different uses of land, the restriction of the SDMs was performed independently for each species. Finally, land cover data classified as urban, water bodies, and permanent snow/ice were masked from the analysis.

For each species, we summarize the following information: taxonomy – following MacKenna and Bell (1997) for suprageneric categories, and Wilson and Reeder (2005) for species and genera; the SDMs or the localities recorded; the common name in English, Spanish, and the local names (see Superina and Aguiar 2006); the number of records for each species; the ecoregions where the species is present (see Figure 1; Burkart et al. 1999); the percentage of area overlapped (using the MaxEnt model); the provinces of Argentina where the species occurs (see Figure 1), based on specific locations; the most frequent habitat where the species has been found (follow Wetzel et al. 2007, Chiarello 2008, among others); the environmental variable/s that contribute the most to the model; the global and local conservation status [International

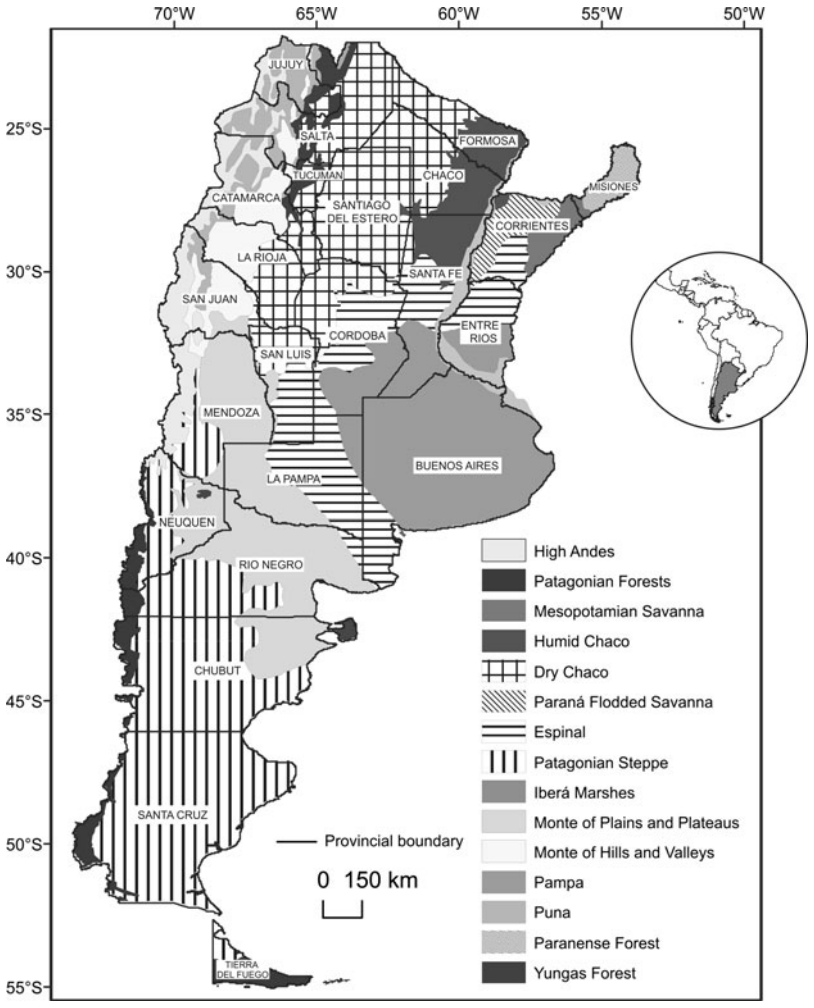

Figure 1 Argentina maps showing ecoregions and provinces names.

Union for Conservation of Nature (IUCN) Red List and Argentine Red List, respectively]; and general comments.

Species distribution models

SDMs were run with the software package MaxEnt (version 3.2.19; Phillips et al. 2006). We selected this modeling method because it has been shown to perform very well with presence-only data (Elith et al. 2006), and with relatively small sample sizes (Hernandez et al. 2006, 2008). MaxEnt uses a statistical mechanics approach called maximum entropy for characterizing probability distributions from incomplete information (Phillips et al. 2006). MaxEnt estimates the probability distribution of maximum entropy (the distribution that is most spread out, or closest to uniform) of the occurrence points across the study area given the constraint that the expected value of each environmental predictor variable under this estimated distribution matches its empirical average (average values for the set occurrence data) (Hernandez et al. 2006, Phillips et al. 2006).

The MaxEnt algorithm was run using the default parameters including a maximum of 500 iterations with a convergence threshold of 0.00001 and 10,000 randomly generated background localities. We used the logistic output, which provides an estimate between 0 and 1 of probability of presence of the modeled species. Species locality data were first filtered so that there was only one record per pixel. We modeled all species that have ≥8 point locality data. This excluded three species (*Bradypus variegatus*, *Dasypus septemcinctus*, and *Calyptophractus retusus*) that are known from only a few localities in Argentina. Several studies have shown that very reliable models can be obtained with low number of occurrences provided that appropriate model validation techniques are employed (Pearson et al. 2007, Kremen et al. 2008). Accordingly, we used very stringent criteria to validate all models. First, all species were modeled 100 times, randomly selecting 75% of the points to generate the models and the remaining 25% to test them. For each of the 100 model runs, we used the testing points to calculate the area under the curve (AUC) for the receiver operating characteristic. The AUC reflects the proportion of both correctly and incorrectly classified predictions over a range of probability thresholds (Pearce and Ferrier 2000) and is positively correlated with the predictive ability of the model (Manel et al. 2001). From the 100 model runs, we were able to calculate the mean AUC value and 95% confidence intervals. Second, models for which the lower limit of the 95% confidence interval of the mean AUC were >0.75 were kept. According to Elith et al. (2006), models that have an AUC value >0.75 have a useful amount of discrimination. Because species with less than 11 point localities have <100 number of training and testing combinations for calculating the 95% confidence intervals (Kremen et al. 2008), we used the actual number of possible combinations. Finally, for all species that met these criteria, we calculated a mean habitat suitability map by averaging all 100 runs for each species.

Results

We obtained a total of 975 records corresponding to 706 different collecting localities from Argentina, and ranging from three to 236 for different species. We were able to plot 15 maps of the 18 species cited for Argentina. The average AUC value for all 15 species was 0.908 (range 0.805–0.994), and the average 95% lower confidence interval for all species was 0.902 (range 0.798–0.994). All models had very good discrimination as their lower confidence interval values were >0.75. The predictive distribution models indicate that arid Chaco (14 species), Yunga Forest (12), and humid Chaco (10) are the ecoregions with the highest diversity of xenarthrans (see "Ecoregions richness"; Figure 6). The province (see Figure 1) with highest number of collecting localities was Buenos Aires (20.5%), followed by Santa Fe (85, 12%) and Chubut (81, 11.5%); the provinces with the highest number of species, based on locality records, were Chaco and Salta (11 species) and Formosa (9). We were able to find specimen records for 17 species and only 15 had enough locality data for running the models. The only species for which we could not find locality records was *Bradypus variegatus*. Two species, *Dasypus septemcinctus* and *Chaetophractus nationi*, have taxonomic problems (see below). Following are the accounts with the information for each of the xenarthran species that occur in Argentina.

MAGNORDER Xenarthra Cope, 1889
ORDER Pilosa Flower, 1883
SUBORDER Phyllophaga Owen, (1842)
FAMILY Bradypodidae Gray, 1821
Bradypus variegatus Schinz, 1825
Common name: Brown-throated three-toed sloth, Perezoso de tres dedos.
Number of records: 1 (no locality assigned).
Ecoregions: Yungas Forest.
Argentine provinces: Jujuy.
Habitat: This species is almost exclusively arboreal and, like all the sloths, it is restricted to forest habitats. It feeds mostly on leaves and, to a lesser extent, on fruits and flowers (Chiarello 2008).
Conservation status: Least Concern (IUCN Red List), Data Deficient (Argentine Red List).
Comments: The only known material that has been assigned to Argentina is deposited in the Field Museum of Natural History (FMNH 21672), and corresponds to a specimen collected in 1916 in Jujuy Province. Another data is provided by a renowned director of the Buenos Aires Zoo, Dr. Clemente Onelli, who led this institution in the early 19th century for 20 years. Onelli (1913) reported two specimens in captivity that came from Jujuy Province and Bertoni (1914) one specimen (that he refers, probably erroneously, as *Bradypus tridactylus*) from San Pedro, Misiones, although he did not collect a specimen. Yepes (1928) proposed their distribution to the west of Chaco, Salta, and Jujuy. Wetzel et al. (2007), following Bertoni (1914) and Yepes (1928), cited *B. variegatus* as present in Salta and Misiones. As it has never been collected or seen again, this species is presumed to be extinct in Argentina

(Díaz and Ojeda 2000, Vizcaíno et al. 2006, Superina et al. 2010b).

SUBORDER Vermilingua Illiger, 1811
FAMILY Myrmecophagidae Gray, 1825
Myrmecophaga tridactyla Linnaeus, 1758
Figure 2A
Common name: Giant anteater, Oso hormiguero, Yurumí.
Number of records: 47.
Ecoregions: Arid Chaco (54%), humid Chaco (20%), Iberá marshes (6%), Paranaense Forest (5%), Yungas Forest (5%), Mesopotamian savanna (5%).
Argentine provinces: Chaco, Corrientes, Formosa, Misiones, Salta, Santa Fe, Santiago del Estero.
Habitat: This species lives in lowlands and savannas, inhabiting a variety of forest and grassland habitats. It is terrestrial and feeds mainly on ants (Wetzel et al. 2007).
Relative importance of environmental variables: Precipitation of warmest quarter (41%), annual mean temperature (33%).
Conservation status: Vulnerable (IUCN Red List and Argentine Red List).
Comments: Although the giant anteater is probably present in Jujuy and Tucumán provinces, there are no specific data available for those areas (Vizcaíno et al. 2006). This species may have occurred as far south as Córdoba Province, but it is now extinct there (Chebez 2006). There is a specimen from La Plata, Buenos Aires Province, that Wetzel et al. (2007) included in his revision, but this may be a confusion with a zoo animal (Gerrard 1862, "Skull. La Plata. From M. Bravard's Collection").

The distribution model shows three areas of high probability of occurrence: one is represented in the humid Chaco, another in the Yungas Forest and arid Chaco, and the third one is a small area located in the Paranaense Forest. In summary, we can confirm this group as Chacoan, due to 64% of their distribution is recorded in this ecoregion. Our model is similar to the last updated of *M. tridactyla* distribution (see Superina et al. 2010a).

Tamandua tetradactyla Linnaeus, 1758
Figure 2B
Common name: Southern tamandúa, Oso melero, Tamandúa.
Number of records: 56.
Ecoregions: Arid Chaco (46%), humid Chaco (16%), Espinal (11%), Iberá marshes (6%), Yungas Forest (5%).
Argentine provinces: Corrientes, Chaco, Formosa, Jujuy, La Rioja, Misiones, Salta, Santa Fe, Tucumán.
Habitat: This species inhabits forests and woodlands, where it feeds on ants and termites, mainly extracted from arboreal nests (Wetzel et al. 2007).
Relative importance of environmental variables: Precipitation of warmest quarter (77.9%).
Conservation status: Least Concern (IUCN Red List), Near Threatened (Argentine Red List).

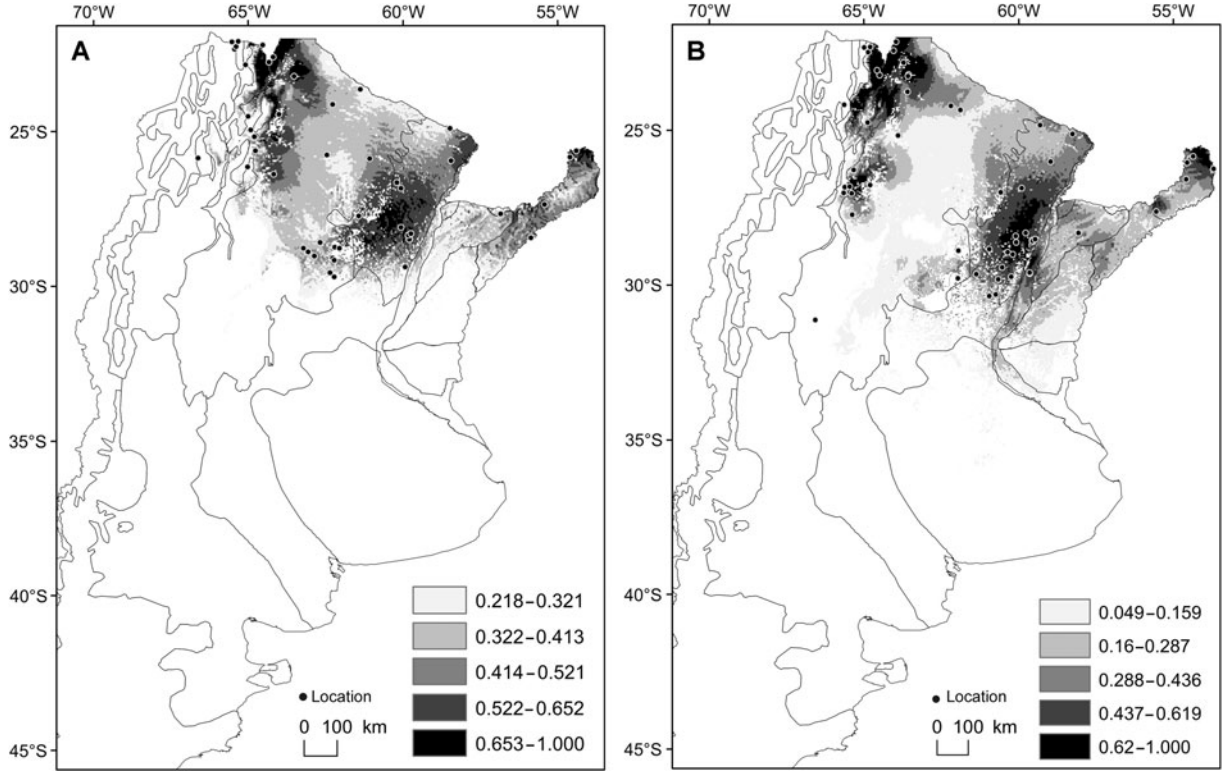

Figure 2 Models of potential distribution of anteaters. (A) *Myrmecophaga tridactyla*. (B) *Tamandua tetradactyla*. The black dots are specific localities where the species was recorded compiled from the literature, specimens in museum collections, and results of recent field work. Gray tone shading indicates presence probability; solid black and white represent the highest and lowest probability, respectively.

Comments: Mares et al. (1996) and Chebez (in Díaz and Ojeda 2000), mention the Southern Tamandua for marginal areas of its distribution as the provinces of Córdoba and Entre Ríos.

Like the giant anteater, the model of southern Tamandúa shows three areas of high probability of occurrence, one in humid Chaco and another in the Yungas Forest and arid Chaco. In contrast to many previous distribution maps (e.g., Wetzel 1985, Gardner 2007, Aguiar and Fonseca 2008), our model indicates that there is suitable habitat for the occurrence of the species further south than the current range.

ORDER Cingulata Illiger, 1811
FAMILY Dasypodidae Gray, 1821
SUBFAMILY Dasypodinae Gray, 1821
TRIBE Dasypodini Gray, 1821
Dasypus hybridus Desmarest, 1804
Figure 3A
Common name: Southern long-nosed armadillo, Mulita orejuda, Mulita pampeana.
Number of records: 89.
Ecoregions: Pampa (27%), Espinal (20%), Monte of plains and plateaus (16%), arid Chaco (15%), humid Chaco (7%).
Argentine provinces: Buenos Aires, Chaco, Córdoba, Corrientes, Entre Ríos, Jujuy, La Pampa, Mendoza, Misiones, Santa Fe.
Habitat: This species usually occurs in grassland habitats, and has been found at elevations from near sea level to as high as 2300 m (Abba et al. 2007, Wetzel et al. 2007).
Relative importance of environmental variables: Precipitation of driest quarter (47.8%).
Conservation status: Near Threatened (IUCN Red List and Argentine Red List).
Comments: This species has been cited for Santiago del Estero and Formosa (Vizcaíno et al. 2006, Abba and Vizcaíno 2008), but there are no locality records from those provinces. Braun and Díaz (1999) cite it as probable for Catamarca Province. Roig (1965, 1991) suggests that this species may have occurred as far south as Mendoza and Río Negro.

The modeled distribution shows that the highest probability of occurrence for this species is the Pampas, particularly in the eastern portion of this ecoregion. In the northeast of Argentina, the model shows intermediate probabilities of occurrence. Another area of high probability of occurrence of this species appears in the humid Chaco; however, this is practically disconnected with the eastern populations. The latter record could be misidentifications with other *Dasypus* species (e.g., *Dasypus yepesi*, see Vizcaíno 1995).

Dasypus novemcinctus Linnaeus, 1758
Figure 3B
Common name: Nine-banded armadillo, Mulita grande, Tatu negro.
Number of records: 59.
Ecoregions: Humid Chaco (21%), arid Chaco (20%), Espinal (18%), Paraná flooded savanna (10%), Pampa (9%), Iberá marshes (8%), Paranaense Forest (5%), Mesopotamian savanna (5%).
Argentine provinces: Corrientes, Chaco, Entre Ríos, Formosa, Misiones, Salta, Santa Fe.
Relative importance of environmental variables: Precipitation of the wettest month (42.6%), precipitation of the warmest quarter (20.8%).
Habitat: This species occupies a variety of forest and savanna habitats, feeding extensively on invertebrates and also fruits, eggs, small vertebrates, and carrion (Wetzel et al. 2007).
Conservation status: Least Concern (IUCN Red List and Argentine Red List).
Comments: There were no specific data for the provinces of Jujuy and Santiago del Estero, probably because of the lack of field surveys in those areas. There are three records in Buenos Aires Province that were not included in this study because it is highly likely that there are accidental records. Two of them

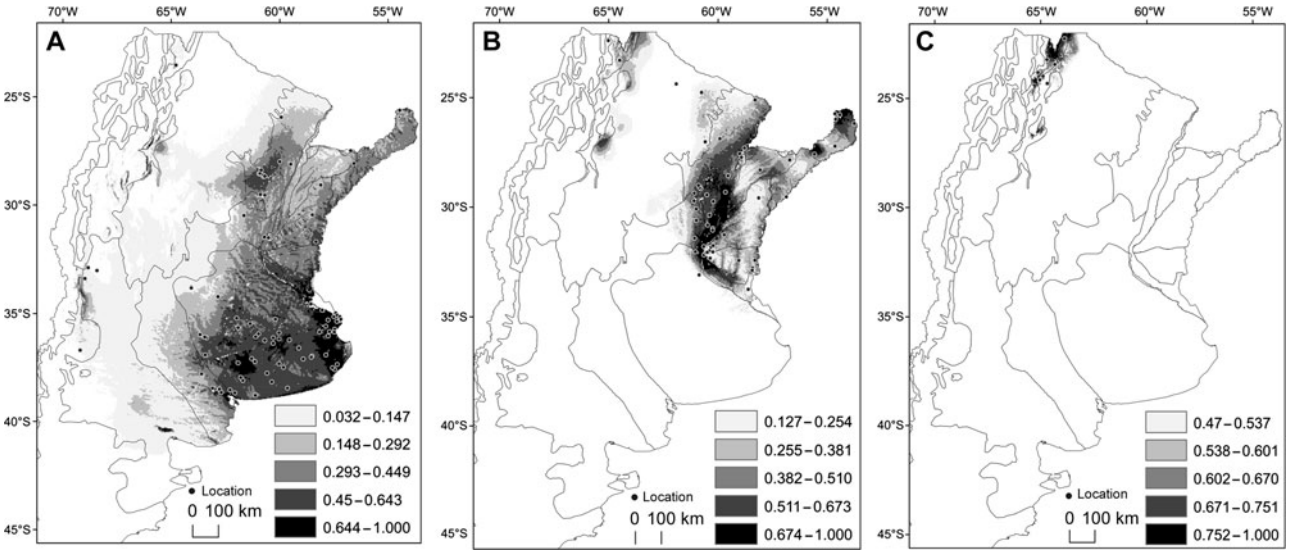

Figure 3 Models of the potential distribution of *Dasypus* species. (A) *Dasypus hybridus*. (B) *Dasypus novemcinctus*. (C) *Dasypus yepesi*. Other references as in Figure 2.

are specimens collected on the margins of the La Plata River in the north of the province (Moschione et al. 1995, see MLP 1.I.03.14), and another record is from the southeast of the province (Zamorano and Scillato-Yané 2008, see MLP 1.I.03.9).

The model shows a region of high probability of occurrence along the Paraná River and in the humid Chaco, and two areas in the Misiones Province (northeastern Argentina). In the northwest, there are two areas of intermediate probability of occurrence that are disjoint from the main predictive distribution area; this could be due to a paucity of field work in the arid Chaco.

Dasypus septemcinctus Linnaeus, 1758
Common name: Seven-banded long-nosed armadillo, Mulita chica.
Number of records: 2.
Ecoregions: Arid Chaco, humid Chaco.
Argentine provinces: Chaco, Salta.
Habitat: This species inhabits savannas, grasslands, and occasionally, gallery forests (Wetzel et al. 2007).
Conservation status: Least Concern (IUCN Red List), Data Deficient (Argentine Red List).
Comments: Hamlett (1939) suggests that this taxon is exclusive from southern Brazil, and that it does not occur in Argentina. Only two specimens from Argentina that have been assigned to this species (see Wetzel and Mondolfi 1979) are available in museum collections (Museo Argentino Ciencias Naturales "Bernardino Rivadavia"); however, morphological evidence is inconclusive and further surveys are needed to verify its presence in this country. Vizcaíno et al. (2006) compiled the literature that reported this species from Corrientes, Formosa, Jujuy, and Misiones provinces. However, it is very likely that these records correspond to the sibling species *Dasypus hybridus*, which is certainly recorded in those provinces. The latter species was considered for many years a junior synonym of *Dasypus septemcinctus* (Wetzel and Mondolfi 1979, Vizcaíno 1995), and may explain the confusion.

Dasypus yepesi Vizcaíno, 1995
Figure 3C
Common name: Yepes' long-nosed armadillo, Mulita de Yepes.
Number of records: 11.
Ecoregions: Yungas Forest (54%), arid Chaco (46%).
Argentine provinces: Jujuy, Salta.
Habitat: Xeric Chacoan habitats as low as 440 m to humid lower montane forests at elevations as high as 1800 m (Vizcaíno 1995, Vizcaíno and Gialombrado 1997).
Relative importance of environmental variables: Precipitation of warmest quarter (51.7%).
Conservation status: Data Deficient (IUCN Red List and Argentine Red List).
Comments: This species was recognized by Vizcaíno (1995) and includes specimens previously assigned to *Dasypus mazzai* (Yepes 1933, Cabrera 1957, Olrog 1976, 1979), *Dasypus hybridus*, *Dasypus septemcinctus*, and *Dasypus novemcinctus* (Wetzel and Mondolfi 1979).

The model is very restricted to the northwest of Argentina associated to Yungas Forest and, to a lesser extent, to the dry Chaco.

SUBFAMILY Euphractinae Winge, 1923
TRIBE Euphractini Winge, 1923
Chaetophractus nationi Thomas, 1894
Figure 4A
Common name: Andean hairy armadillo, Quirquincho andino.
Number of records: 9.
Ecoregions: Puna (47%), Monte of hills and valleys (30%), high Andean (15%), Yungas Forest (5%).
Argentine provinces: Jujuy, Tucumán.
Relative importance of environmental variables: Precipitation seasonality (49.6%), elevation (26.6%).
Conservation status: Vulnerable (IUCN Red List), Data Deficient (Argentine Red List).
Habitat: This species lives in grassland and brushy habitats of the high-elevation Andean Puna ecoregion (Wetzel et al. 2007).
Comments: The taxonomic identity of this species is unclear and it has been proposed that it can be a high-elevation subspecies of *Chaetophractus vellerosus* (Wetzel 1982, 1985). There are no locality records from Salta Province, where once was recorded (Vizcaíno et al. 2006).

The predictive model for this species is very fragmented, with a high probability of occurrence in the Puna Desert. In the latest updates of *Chaetophractus nationi* distribution (see Aguiar and Fonseca 2008, Abba and Superina 2010), the limit of the range is in the northernmost region of Argentina; however, the model predicts suitable habitat for this species farther to the south.

Chaetophractus vellerosus Gray, 1865
Figure 4B
Common name: Screaming hairy armadillo, Piche llorón.
Number of records: 115.
Ecoregions: Arid Chaco (32%), Espinal (14%), Pampa (12%), Monte of plains and plateaus (12%), Monte of hills and valleys (8%), Puna (6%).
Argentine provinces: Buenos Aires, Catamarca, Chaco, Córdoba, Formosa, Jujuy, La Pampa, La Rioja, Mendoza, Neuquén, Salta, San Juan, San Luis, Santa Fe, Santiago del Estero, Tucumán.
Habitat: This species inhabits xeric habitats from low to high elevations (Abba et al. 2007, 2011, Wetzel et al. 2007).
Relative importance of environmental variables: Precipitation seasonality (15.6%), precipitation of warmest quarter (14.6%).
Conservation status: Least Concern (IUCN Red List and Argentine Red List).
Comments: With 115 records, the screaming hairy armadillo is the 3rd most well-known xenarthran of Argentina.

The model reveals a widespread species, with areas of high probability of occurrence spread around the center and northwest of Argentina. Other area of high probability of occurrence is in the northeast of the Pampas Grassland. This was described as an isolated population (Crespo 1974, Carlini and

Vizcaíno 1987, Abba et al. 2011) and the model support this hypothesis.

Chaetophractus villosus Desmarest, 1804
Figure 4C
Common name: Large hairy armadillo, Peludo, Quirquincho grande.
Number of records: 247.
Ecoregions: Patagonian Steppe (19%), Pampas Grassland (18%), arid Chaco (18%), Monte of plains and plateaus (16%), Espinal (13%).
Argentine provinces: Buenos Aires, Catamarca, Chaco, Chubut, Córdoba, Entre Ríos, Formosa, La Pampa, La Rioja, Mendoza, Neuquén, Río Negro, Salta, San Luis, Santa Cruz, Santa Fe, Santiago del Estero, Tierra del Fuego.
Habitat: This species is found in a wide range of habitats, but it seems to prefer grasslands (Cabrera and Yepes 1940, Abba et al. 2007, 2010).
Relative importance of environmental variables: Elevation (17.6%), precipitation of coldest quarter (13.8%).
Conservation status: Least Concern (IUCN Red List and Argentine Red List).
Comments: This is the species with most records and the model indicates that is one of the most widespread armadillo in Argentina. The Pampas Grassland is the area of highest probability of occurrence. The population of Tierra del Fuego was introduced probably in 1985 (Poljak et al. 2007). The absence from the Mesopotamian region (Entre Ríos, Corrientes and Misiones) is not known (see Abba and Vizcaíno 2008, Pautasso 2009), the record from Entre Ríos is a specimen found off the coast of the Paraná River (Abba and Vizcaíno 2008).

Euphractus sexcintus Linnaeus, 1758
Figure 4D
Common name: Six-banded armadillo, Gualacate, Gualincho.
Number of records: 44.
Ecoregions: Arid Chaco (41%), Espinal (15%), humid Chaco (14%), Yungas Forest (6%), Iberá marshes (6%).

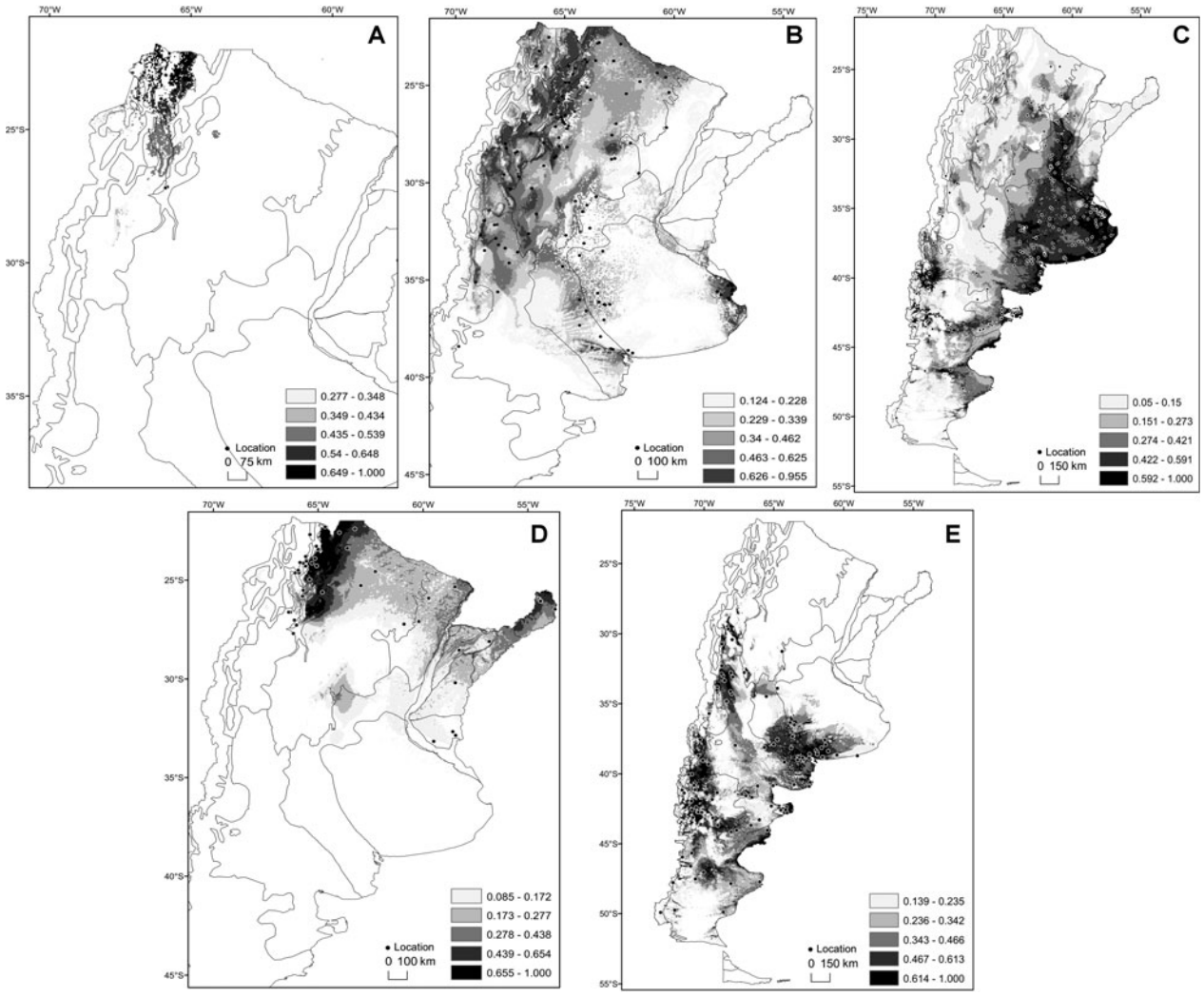

Figure 4 Model of the potential distribution of Euphractini species. (A) *Chaetophractus nationi*. (B) *Chaetophractus vellerosus.* (C) *Chaetophractus villosus.* (D) *Euphractus sexcintus*. (E) *Zaedyus pichiy*. Other references as in Figure 2.

Argentine provinces: Corrientes, Chaco, Entre Ríos, Formosa, Jujuy, Misiones, Salta, Tucumán.
Habitat: The optimal habitat for this species is probably savanna, forest edge, and steppe (Wetzel 1985).
Relative importance of environmental variables: Precipitation of warmest quarter (54.1%).
Conservation status: Least Concern (IUCN Red List and Argentine Red List).
Comments: This species has not been recorded in the provinces of Catamarca and Santiago del Estero, probably due to the lack of field work. Wetzel et al. (2007) suggested that the distribution of this armadillo reaches General Lavalle, Buenos Aires. However, the specimen for this record is deposited in the Museum of Comparative Zoology, Harvard University (No. 19502), and its location is reported as "Argentina, Gral. LaValle, 10 miles southwest of Gral. LaValle," without specifying the province. Therefore, it would be a speculation to assume that is in Buenos Aires because there are several localities with that name in different provinces of Argentina (e.g., Corrientes, Formosa, Salta, Mendoza).

The model shows an area of high probability of occurrence in the northwest and, to a lesser extent, in northeastern Argentina. This species is common in the Mesopotamian region; however, there are few records from this area. An interesting result of the predictive model is that in central Argentina, around the Sierras Grandes of Cordoba, appears a core of intermediate probability of occurrence, which coincides with a recent finding of a plaque of species at an archaeological site (Medina, M.E., pers. comm.), suggesting that the species may have occurred there in the past.

Zaedyus pichiy Desmarest, 1804
Figure 4E
Common name: Pichi, Piche de oreja corta, Piche patagónico.
Number of records: 117.
Ecoregions: Patagonian Steppe (40%), Monte of plains and plateaus (26%), Pampas grassland (13%), Espinal (11%).
Argentine provinces: Buenos Aires, Chubut, Córdoba, La Pampa, La Rioja, Mendoza, Neuquén, Río Negro, San Juan, San Luis, Santa Cruz.
Habitat: Pichis live in arid habitats with firm sandy or poor volcanic soils, grasslands with isolated shrubs, areas with open bush communities, and basaltic steppes (Superina 2008, Abba et al. 2010).
Relative importance of environmental variables: Mean temperature of coldest quarter (17.5%), precipitation of warmest quarter (14.3%).
Conservation status: Near Threatened (IUCN Red List and Argentine Red List).
Comments: This is the second species with more records. The model reflects a wide distribution in the southern part of Argentina, but it also shows areas of habitat suitability for this armadillo in valleys of the northwestern portion of the country.

TRIBE Chlamyphorini Pocock, 1924
Calyptophractus retusus Burmeister, 1863
Common name: Chacoan fairy armadillo, Pichiciego mayor.
Number of records: 3.
Ecoregions: Arid Chaco.
Argentine provinces: Salta.
Habitat: This species is presumed to be largely fossorial, inhabiting the Chacoan region (Wetzel et al. 2007).
Conservation status: Data Deficient (IUCN Red List and Argentine Red List).
Comments: Although it was cited for Chaco and Formosa (Vizcaíno et al. 2006) there were no data points for these provinces. The locality of Tapia, in Formosa Province, was excluded because we were uncertain of its accuracy. Despite the inability to develop a model for this species, we can ascertain that it is mainly limited to the arid Chaco.

Chlamyphorus truncatus Harlan, 1825
Figure 5A
Common name: Pink fairy armadillo, Pichiciego menor, Pichiciego pampeano.
Number of records: 54.
Ecoregions: Monte of plains and plateaus (36%), Espinal (29%), arid Chaco (20%), Monte of hills and valleys (8%), Pampas Grassland (5%).
Argentine provinces: Buenos Aires, Catamarca, Córdoba, La Pampa, La Rioja, Mendoza, Río Negro, San Juan, San Luis.
Habitat: This is a nocturnal species, found in dry grassland and sandy plains with shrubby vegetation (Abba and Superina 2010).
Relative importance of environmental variables: Temperature annual range (47%).
Conservation status: Data Deficient (IUCN Red List and Argentine Red List).
Comments: This species is endemic to Argentina. Most of the localities where it has been recorded come from Mendoza Province (22) in central western Argentina. In this area, the model predicts a higher probability of occurrence.

SUBFAMILY Tolypeutinae Gray, 1865
TRIBE Tolypeutini Gray, 1865
Tolypeutes matacus Desmarest, 1804
Figure 5B
Common name: Southern three-banded armadillo, Mataco, Quirquincho bola.
Number of records: 79.
Ecoregions: Arid Chaco (44%), Espinal (11%), humid Chaco (10%), Monte of plains and plateaus (9%), Pampas grassland (9%), Monte of hills and valleys (5%).
Argentine provinces: Buenos Aires, Catamarca, Córdoba, Chaco, Formosa, Jujuy, La Rioja, Mendoza, Salta, San Luis, Santa Fe, Santiago del Estero, Tucumán.
Habitat: This species is found in xeric habitats (Wetzel et al. 2007).
Relative importance of environmental variables: Precipitation of warmest quarter (26.7%), precipitation seasonality (17%).
Conservation status: Near Threatened (IUCN Red List and Argentine Red List).
Comments: Although it was cited for La Pampa and San Juan (Vizcaíno et al. 2006) there were no data points for

these provinces. The records from southern Buenos Aires Province are very old, and the model shows a discontinuity between this area and the more continuous central-northern area of distribution. This discontinuity reflects an area of intensive agriculture in the humid Pampas. Given this, we can assume that, at present, the probability of finding this species in Buenos Aires Province is very low. The model predicts a high probability of occurrence in the Yungas Forest, but the arid Chaco is the ecoregion where this species is more abundant (see Bolkovic et al. 1995, Agüero et al. 2005).

TRIBE Priodontini Gray, 1873
Cabassous chacoensis Wetzel, 1980
Figure 5C
Common name: Chacoan naked-tailed armadillo, Cabasú chaqueño, Cabasú chico, Tatú de rabo molle.
Number of records: 11.
Ecoregions: Arid Chaco (70%), humid Chaco (20%).
Argentine provinces: Chaco, Formosa, La Rioja, Santiago del Estero, Santa Fe.
Habitat: *Cabassous chacoensis* has been reported to inhabit grassland and upland plateaus of the Gran Chaco region (Wetzel 1980).
Relative importance of environmental variables: Mean temperature of wettest quarter (70%).
Conservation status: Near Threatened (IUCN Red List and Argentine Red List).
Comments: There are no locality data for Tucumán Province where it has been recorded (Vizcaíno et al. 2006). In the last years, it was recorded outside its known distribution (Nellar et al. 2008, Monguillot and Miatello 2010). However, before the formal description of the species made by Wetzel (1980), Moeller (1968) had found it in areas of central Argentina. This author reviews a specimen collected in San Luis (Villa Mercedes, Ea. Don Roberto) by the Herre/Röhrs expedition and named it *Cabassous loricatus* Yepes, 1935; but it was clearly *C. chacoensis*. In summary, this species was originally known from the northern portion of the Chaco, probably due to the lack of surveys. The model indicates that this is a typical Chacoan species; however, it also shows an intermediate probability of occurrences in the Monte ecoregion, where it has been recently recorded by Monguillot and Miatello (2010).

Cabassous tatouay Desmarest, 1804
Figure 5D
Common name: Greater naked-tailed armadillo, Cabasú grande, Tatuay.

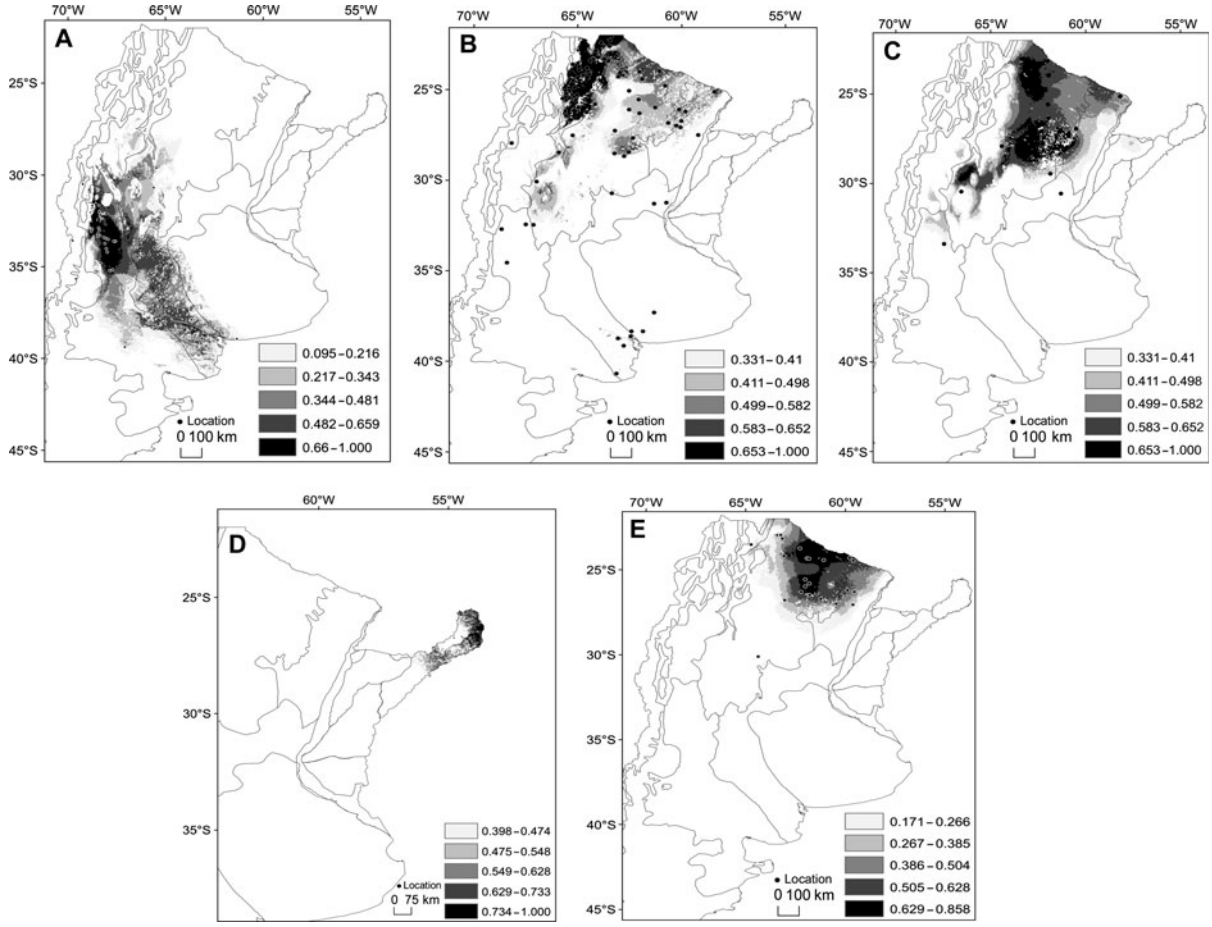

Figure 5 Model of the potential distribution of Chlamyphorini, Tolypeutini, and Priodontini species. (A) *Chlamyphorus truncatus.* (B) *Tolypeutes matacus.* (C) *Cabassous chacoensis.* (D) *Cabassous tatouay.* (E) *Priodontes maximus.* Other references as in Figure 2.

Number of records: 9.
Ecoregions: Paranaense Forest (76%), Mesopotamian savanna (22%).
Argentine provinces: Corrientes, Misiones.
Habitat: This species appears to prefer savanna habitats and is highly fossorial (Wetzel et al. 2007).
Relative importance of environmental variables: Precipitation of driest month (62.4%).
Conservation status: Least Concern (IUCN Red List), Vulnerable (Argentine Red List).
Comments: Wetzel et al. (2007) states that the Greater naked-tailed armadillo "is found in Uruguay, the Argentine provinces of Misiones and Buenos Aires (exact location unknown, not mapped; Moeller 1968)," but the record from Buenos Aires is most likely an error because this armadillo is typical from the northern part of Argentina. The model shows a high probability of occurrence in the Paranaense Forest, highly associated with precipitation.

Priodontes maximus Kerr, 1792
Figure 5E
Common name: Giant armadillo, Tatú carreta, Tatú-guazú.
Number of records: 22.
Ecoregions: Arid Chaco (74%), humid Chaco (23%).
Argentine provinces: Chaco, Córdoba, Formosa, Salta, Santiago del Estero.
Habitat: Giant armadillos are nocturnal, highly fossorial, and tolerant of a range of habitats that includes tropical rainforest and open savanna (Wetzel et al. 2007).
Relative importance of environmental variables: Annual mean temperature (59%).
Conservation status: Vulnerable (IUCN Red List), Endangered (Argentine Red List).
Comments: Records from Córdoba are very old, and it is very likely that the species does not occur there at present. The model clearly shows that, in Argentina, is a typical Chacoan species. This restriction to a single habitat is completely opposite to the rest of the distribution where it is found in many distinct habitats (e.g., forest, savanna, grassland; see Anacleto and Diniz 2006, Aguiar and Fonseca 2008, Superina et al. 2009, Abba and Superina 2010).

Ecoregions richness

The highest richness of species in Argentina is in the north and northeast of the country, mainly in the Chaco ecoregion (humid and arid), followed by the Yungas and Paranaense forests, the Mesopotamian savanna, and the Iberá marshes (Figure 6). The Monte and Espinal ecoregions have areas with intermediate richness, and the remaining ecoregions, mainly in western and southern Argentina, have low species richness. This pattern may reflect the low tolerance of many species to areas of lower precipitations and lower temperatures in the south of the country, in addition to high elevations along the Andes Mountains in the western portion of the country. Also, it is very likely that many species had ranges that extended farther south in the humid Pampas; however, most of that ecoregion has been converted to agricultural lands in the past century.

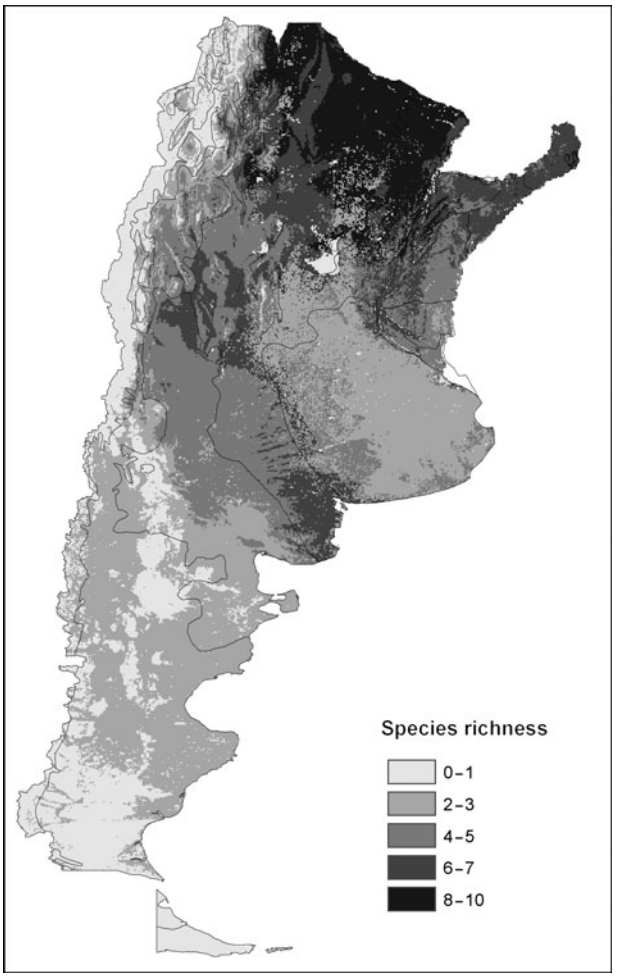

Figure 6 Species richness of xenarthrans in Argentina. Gray tone shading indicates species richness, solid black and white representing the highest and lowest values, respectively.

Discussion

Virtually all of Argentina is occupied by xenarthrans, despite the large area, the latitudinal and altitudinal range, and the heterogeneity of habitats of the country. In the preceding sections, we compiled georeferenced information on the distribution of xenarthrans in Argentina form the literature and museum collections, considering changes in land cover that may have occurred since then must be taken into account, and updating as much as possible with our own field data. For most species, we collected a reasonable amount of georeferenced data, being good for *Chaetophractus villosus*, *Zaedyus pichiy*, *Chaetophractus vellerosus*, *Dasypus hybridus*, and *Tolypeutes matacus*, and something poorer for *Dasypus novemcinctus*, *Tamandua tetradactyla*, *Chlamyphorus truncatus*, *Myrmecophaga tridactyla*, *Euphractus sexcintus*, and

Priodontes maximus. For the remaining species (*Dasypus yepesi*, *Dasypus septemcinctus*, *Cabassous chacoensis*, *Chaetophractus nationi*, *Cabassous tatouay*, *Calyptophractus retusus*, *Bradypus variegatus*), although present in most ecoregions within the country, very few data is available for this group, probably due to the lack of field studies or deficiencies in the publication of the information. This problem was also reported by Anacleto and Diniz (2006) who noted that the amount of exact place of collection or sighting of armadillos in Brazil is rarely reported. In this sense, the application of SDMs is an extremely useful tool to map potential distributions of these species and to assess patterns of species richness of this important group of mammals in Argentina.

Myrmecophaga and *Tamandua*, the two anteaters present in Argentina, show similar potential distribution patterns. These species have three cores of high probability of occurrence, two in forest habitat and one in the Chaco ecoregion. Both distribution models are similar to what has been depicted as the geographic range for these species (see Figure 2A,B; Gardner 2007, Superina et al. 2010a). The model of *Tamandua tetradactyla* is more widespread, showing areas of probable occurrence farther south than it was previously recorded. This may be due to the higher level of plasticity and adaptability of this species (Redford and Eisenberg 1992).

The potential distribution of the species of *Dasypus* is highly influenced for precipitation and shows relatively high overlapping. However, the analysis of occurrence between habitat types shows a habitat differentiation for these species. The model of *Dasypus hybridus* shows a wide occurrence in the eastern region of Argentina, principally in grasslands habitat, *Dasypus novemcinctus* shows high probability in forest regions of the east and, finally, *Dasypus yepesi* is highly restricted to the Yungas Forest. There is a wide area in the western portion of the Chacoan ecoregion where the models do not predict potential habitat availability for all *Dasypus* species. However, the absence of locality records from this area may be due to the lack of surveys.

Three of five species of euphractines do not show a strong association with any particular environmental variable (*Chaetophractus vellerosus*, *Chaetophractus villosus*, and *Zaedyus pichiy*), while *Euphractus sexcintus* is clearly influenced by precipitation. While the first three euphractine species may have evolved in area including most of the semiarid central region of Argentina (see Soibelzon et al. 2006, Poljak et al. 2010), *E. sexcinctus*, is a mostly Brazilian species, not adapted to the dryer environments present in Argentina.

The predicted ranges of *Chaetophractus nationi* and *Chaetophractus vellerosus* show a high overlap between them, which is coherent with Wetzel's (1982, 1985) suggestion that proposes that *C. nationi* is a subspecies of *C. vellerosus* that lives in high-altitude areas. The predicted distributions of the two widespread *Chaetophractus* species (*C. villosus* and *C. vellerosus*) also show a high overlap between them. While *C. villosus* has a higher probability of occurrence in grassland habitat in the central eastern portion of the country, *C. vellerosus* has a higher probability in west central Argentina with desert and semi-desert habitats. In addition, the model of *C. vellerosus* confirms the isolation of the population in the eastern portion of the range in Buenos Aires Province.

The model for *Chlamyphorus truncatus* presents a highest probability of occurrence in east center of Argentina (Monte of plains and plateaus ecoregion, Mendoza Province). This may be due to a combination of environmental feature.

The model of *Tolypeutes matacus* has middle a low probability of occurrence in the center of Argentina, even though this species actually do not overcome the 33° latitude south.

The two *Cabassous* species have probability of occurrence in few habitat regions of Argentina. However, Anacleto and Diniz (2006) present a wide spread model for *Cabassous tatouay* that is not real because the records of this species are restricted to a small region of the northeast of the country. This mistake may be due to erroneous records documented several years ago in Buenos Aires Province (see comments in Results section).

According to the model and empiric information, *Priodontes maximus* in Argentina is restricted to the Chacoan ecoregions. However, in historic times (around 1870), this species was recorded further south; this difference may be due to the modification of habitat by human activities, principally by deforestation.

As mentioned above, the highest richness of species is in the north and northeast of the country in the humid and arid Chaco, probably in relation with the mosaic of ecosystems recorded in these regions, allowing the coexistence of different species (of different lineages) with diverse habitat requirements. A similar pattern, with a high diversity of habitats and up to nine species of armadillos is observed in the neighbor Cerrado, has led Anacleto and Diniz (2006) to claim that the Cerrado is an important hotspot for the armadillos of Brazil. Other hotspots of richness are present in both subtropical forest (Paranense and Yunga Forest) and the Iberá marshes, northern areas of Mesopotamian savanna and Espinal. Then, the species richness started to decline and showed degradation to the south. This pattern was previously observed in other South American mammals (Kaufman and Willig 1998, Tognelli and Kelt 2004), and this degradation is mainly explained by the fall of primary productivity and temperature (Tognelli and Kelt 2004).

Species that have a complex conservations status (*Bradypus variegatus*, *Myrmecophaga tridactyla*, *Calyptophractus retusus*, *Cabassous chacoensis*, *Cabassous tatouay*, and *Priodontes maximus*) are not very well studied and, therefore, have lower number of locality data, indicating the necessity of generating information on these taxa as soon as possible. The ecoregions with highest species richness have different degrees of habitat degradation and continues to be a major threat for the viability of the xenarthrans occurring there (see Brown et al. 2006). In a complementary study (Tognelli et al. 2011), we identified priority areas for the conservation of xenarthrans that may help governmental and non-governmental agencies to establish new areas to protect and conserve this important group as well the critical environments where they live.

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