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Occurrence of *Cabassous tatouay* (Cingulata, Dasypodidae) in Rio Grande do Sul and its potential distribution in southern Brazil

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ABSTRACT. *Cabossous tatouay* Desmarest, 1804 is considered a rare species in southern South America, and Rio Grande do Sul State, Brazil, records of the species are scarce and inaccurate. This study reports 40 localities for *C. tatouay*, and provides a map of the species' potential distribution using ecological niche modeling (ENM). The ENM indicated that in this region *C. tatouay* is associated with open grasslands, including the areas of "Pampas" and the open fields in the highlands of the Atlantic Forest. This study contributes to the information about the greater naked-tailed armadillo in southern Brazil, and provides data key to its future conservation.

KEYWORDS. Xenarthra, ecological niche, greater naked-tailed armadillo.

RESUMO. Ocorrência de *Cabassous tatouay* (Cingulata, Dasypodidae) e seu potencial de distribuição para o sul do Brasil. *Cabassous tatouay* Desmarest, 1804 é considerada espécie rara no sul da América do Sul, apresentando registros escassos e imprecisos para o Rio Grande do Sul. O presente estudo descreve 40 localidades de ocorrência de *C. tatouay* e apresenta de um mapa de distribuição geográfica potencial, gerado por Modelagem Ecológica de Nicho. A modelagem de nicho sugere uma associação da espécie com áreas de matriz campestre, incluindo o Pampa e os Campos de Cima da Serra, associados à Mata Atlântica. Este estudo contribui para o melhor conhecimento do tatu-de-rabo-mole no Sul do Brasil e fornece dados-chave para sua conservação.

PALAVRAS-CHAVE. Xenarthra, nicho ecológico, tatu-do-rabo-mole.

Cingulata belonging to the genus *Cabassous* Mc Mutrie, 1831, are represented by four formally described species (Gardner, 2005) of which two occur in Brazil (Paglia *et al.*, 2012; Hayssen, 2014): *Cabassous tatouay* Desmarest, 1804, and *C. unicinctus* (Linnaeus, 1758). The lack of physical records of these two armadillos in national scientific collections, and their infrequent appearance on local inventories, limit detailed studies on their taxonomy, phylogeny, geographical distribution, and conservation status (Fonseca *et al.*, 1996; Nowak, 1999; Anacleto *et al*., 2006).

That *Cabassous tatouay*, greater naked-tailed armadillo, is a poorly known species has been reported by Wetzel (1982), Redford (1985), Ubaid *et al*. (2010), Gonzales & Lanfranco (2010) and Hayssen (2014). The southernmost records of the species are from the Uruguayan provinces of Maldonado and Lavalleja (Coitiño *et al.*, 2013). From here the range extends northwards to the state of Pará, in northern Brazil. In between the species has been recorded from the southern, southeastern, and central regions of Brazil (Hayssen, 2014). It is also found in southern Paraguay (Hayssen, 2014) and northeastern Argentina, where it appears restricted to Misiones province (Abba *et al.*, 2012).

In southern Brazil, the species appears in the regional listings of both Ihering (1892) and Silva (1994), but in both cases without any information on location or habitat. Oliveira & Vilella (2003) mentioned the occurrence of *C. totouay* in the west and southwest regions of the state, and Kasper *et al.* (2007) indicated the occurrence of this species in the central region of RS, where it may be in population decline. The only accurate and confirmed record is from an archaeological site located at east of State, associated to pioneer formations under fluvial influence of the Rio Grande basin. An assessment of potential geographic ranges of armadillos in Brazil (Anacleto *et al.*, 2006) highlighted the small number of *C. tatouay* records, and suggested that Brazilian Pampa was not a favored habitat. Indeed, *C. tatouay* does seem relatively uncommon in this habitat, except in Uruguay, the southern limit of its distribution, where some 10 records are available from the Pampas (Coitiño *et al.*, 2013).

There are few ecological data from the northernmost part of the range of *C. tatouay*. Medri *et al.* (2011) pointed to the occurrence of the species in forested areas, and its absence from areas of intensive agriculture or severely degraded localities. According to Carter & Encarnação (1983), *C. tatouay* changes its burrow every day, and does not use the same shelter twice. Medri *et al.* (2011) reported that the species has a home range of some

409 hectares, feeds exclusively on ants, is predominantly crepuscular or nocturnal, and has only a single offspring at any one time.

The greater naked-tailed armadillo is considered of Least Concern at the global level, with only minor conservation action being proposed (Gonzales & Abba, 2014). However, all available information on the species in Brazil has been derived from a handful of wild-based observations, and these are insufficient to assess the status of the species in the country (Chiarello *et al.*, 2008). *Cabassous tatouay* is considered vulnerable to extinction in Uruguay, and is a national priority for conservation (Gonzales & Lanfranco, 2010). With regard to Rio Grande do Sul, there is no precise information on the population status or even the basic inventories to enable analysis of the current distribution of the species (Oliveira & Vilella, 2003).

Thus, the present study aims to contribute to the knowledge of *C. tatouay* in RS by reporting new areas of occurrence, expanding the known distribution of the species, and providing a map of its potential distribution using ecological niche modeling.

MATERIAL AND METHODS

***Cabassous tatouay* distributional data.** All records of *C. tatouay* were obtained between 2000 and 2012 through monitoring and inventories of mammals in different regions of the Rio Grande do Sul State, plus records of opportunity. The main methods employed were: camera trap records, searching for tracks and signs, nocturnal censuses, *ad libitum* observations, and monitoring mammalian roadkill on regional highways. The results were part of a general program of mammal surveys in the state and did not specifically target *C. tatouay* and covered a range of regional environments. Thus, any reported habitat selection is not the result of selectivity in survey design.

Specimens found dead and with good conditions were deposited in the scientific collections of the Museu de Ciências Naturais, Universidade Luterana do Brasil, Canoas, RS. For specific determination of *C. tatouay*, we followed Eisenberg & Redford (1999), Achaval *et al.* (2007), Medri *et al.* (2011), and Gonzales & Lanfranco (2010) in using the following as diagnostic external characteristics: body large and robust (6–12 kg), shell with 10–13 flexible dorsal bands and tail lacking osteoderms; head large, cephalic shield with symmetrical plates; ears large, widely-separated, and with granular external surface; snout short and wide; front and back legs both with five digits, and large nails, especially on the third digit; dental formula varying between 7 to 10 upper, and 8 to 9 lower teeth. Sampling sites were widely dispersed throughout RS state, and a variety of habitat types including forests, open fields in the highlands of the Atlantic Forest, and formations of Brazilian Pampas. All records of *C. tatouay* were georeferenced.

Ecological niche modeling. A potential distribution map was produced using the Maxent algorithm version 3.2.1 (Phillips *et al.*, 2006) by applying the basic parameters suggested by the program and deploying randomization of training points (random seed). Overlapping or very close points were removed, and *C. tatouay* records were divided into two sets, one for training (75% of points to run the model) and the other for testing (25% of points to evaluate the model). The model of potential geographical distribution generated by Maxent was then imported and edited by the ArcView 3.3 program.

The quality of the model prediction was evaluated using ROC (Receiver Operating Characteristics) that relates the sensitivity and specificity parameters of the model (Phillips *et al.*, 2006). The calculation of the area under the ROC curve, also known as Area Under the Curve (AUC), provides a single measure of the model performance. The AUC ranges from 0 to 1, where values close to 1 indicate high performance, while those less than 0.5 indicate poor performance (Peterson *et al.*, 2008). To evaluate the sensitivity, we tracked the number of test points present in the area predicted by the model (Elith *et al.*, 2006). To identify the variables that most influenced the distribution of *C. tatouay*, we ran a Jackknife test using Maxent (Phillips *et al.*, 2006). This test measures the predictive effects of each variable in the model when verifying the quality of the model only with the variable in test and the omitted variable in test.

Seven predictor variables were used (Tab. I). These variables were obtained from the Modeling Group for Biodiversity Studies, of the Brazilian Institute for Space Research, AMBDATA/INPE (http://www.dpi.inpe.br/Ambdata/referencias.php). All environmental information was organized in grids in the ASCII-raster format, using the geodetic coordinate projection system “Lat Long,” *Datum* WGS-84, with a spatial resolution of 30 arc-seconds or approximately 1 km^2.

RESULTS

Field observations registered 40 occurrences of *C. tatouay* from 30 municipalities within RS. Twenty-seven sites were located in the Pampa biome, eleven in the Atlantic Forest, and two in the areas of transition from Pampa biome to Atlantic Forest (IBGE, 2004) (Tab. II). A total of twelve specimen records were obtained by identifying tracks, ten individuals were directly observed, nine carcasses were obtained from hunters, five carcasses were found as highway roadkill, and four individuals were recorded with camera traps.

For ecological niche modeling, 37 spatially unique records were used. *Annual average temperature* was the variable that most influenced the model distribution of *C. tatouay*, followed by *precipitation in driest month* (Tab. II).

The operating characteristic (OC) curve evaluates the performance of the model. OC analysis gave a value of 0.99, which is regarded as excellent, and indicates that the results were not random. As evaluated by the

Tab. I. Predictor variables used in the ecological niche modeling of *Cabassous tatouay* Desmarest, 1804 for the State of Rio Grande do Sul, Brazil.

Name	Environmental Variable	Percent contribution
Altitute_br	Altitude	2.3
Bio1_br	Average annual temperature	52.3
Bio2_br	Average diurnal temperature variation	6.8
Bio5_br	Maximum temperature of warmest month	0
Bio6_br	Minimum temperature of coldest month	1.1
Bio7_br	annual precipitation	0
Bio13_br	Precipitation of wettest month	6.9
Bio14_br	Precipitation of driest month	28.3
Sa2010_Tree	Percent arboreal coverage	2.3

Tab. II. Confirmed localities for *Cabassous tatouay* Desmarest, 1804 in the State of Rio Grande do Sul, Brazil, 2000–2012, with record date, type of observation, municipality, biome, anthropogenic matrix, and human density (DO, Direct observation; PP, Pawprint; HU, Hunted; RK, Roadkill; CT, Camera trap; RE, Record; BI, Biome; AF, Atlantic Forest; PA, Pampa).

Date	RE	City	Latitude	Longitude	BI	Anthropogenic matrix	Human density
2004	CT	São Francisco de Paula	-31.0427	-54.5375	AF	livestock and *Pinus*	low, latifundia
2004	RK	Santana do Livramento	-29.95972	-50.6711	PA	livestock	low, latifundia
2004	DO	Piratini	-28.8063	-50.6131	PA	eucalyptus and livestock	low, latifundia
2004	DO	Tapes	-30.61411	-53.53258	PA	landscape and forest fragments altered by planting eucalyptus and rice	low, latifundia
2005	RK	Cambará do Sul	-30.2961	-53.53777	AF	livestock and *Pinus*	low, latifundia
2005	PP	São Francisco de Paula	-30.2913	-53.7605	AF	livestock and *Pinus*	low, latifundia
2005	PP	Maquiné	-30.37055	-53.6008	AF	cyclical monocultures	low, latifundia
2005	DO	Capão do Leão	-30.35107	-51.0405	PA	eucalyptus, soya, and livestock	high, minifundios, and urbanization
2005	DO	Arroio Grande	-30.6966	-49.5224	PA	eucalyptus, soya, and livestock	low, latifundia
2006	DO	Rosário do Sul	-28.2333	-51.1833	PA	eucalyptus, livestock, rice, and soya	low, latifundia
2006	PP	Manoel Viana	-28.33305	-50.6966	PA	eucalyptus, livestock, rice, and soya	low, latifundia
2006	PP	São Francisco de Assis	-28.33611	-50.6755	PA	eucalyptus, livestock, rice, and soya	low, latifundia
2006	DO	Alegrete	-29.03027	-51.41916	PA	eucalyptus, livestock, rice, and soya	low, latifundia
2007	RK	São Francisco de Paula	-30.41722	-53.43638	AF	livestock, *Pinus,* and cyclical monocultures	low, latifundia
2007	PP	Piratini	-28.80607	-50.51680	PA	eucalyptus, *Pinus*, and livestock	low, latifundia
2007	HU	Caçapava do Sul	-31.58091	-53.47975	PA	eucalyptus, soya, and livestock	low, latifundia
2007	RK	São Sepé	-31.02008	-53.66596	PA	natural grasslands and forest fragments changed by livestock and planting of soya	low, latifundia
2008	HU	Dom Pedrito	-32.09612	-53.58937	PA	natural rocky grassland and forest fragment used extensively by livestock	low, latifundia
2008	DO	Alegrete	-31.775259	-53.80291	PA	rupestrian field and forest fragment used extensively by livestock	low, latifundia
2009	RK	Viamão	-30.6155	-51.3625	AF /PA	livestock, rice, and urbanization	low, latifundia
2009	PP	Encruzilhada do Sul	-31.84310	-53.5854	PA	eucalyptus, soya, and livestock	low, latifundia
2010	DO	Pedras Altas	-29.0829	-50.3666	PA	eucalyptus and livestock	low, latifundia
2010	RK	Santana da Boa Vista	-31.29572	-53.47415	PA	eucalyptus, soya, and livestock	low, latifundia
2010	RK	Caçapava do Sul	-30.5644	-52.15723	PA	natural rocky grasslands and forest fragment used extensively by livestock	low, latifundia
2011	PP	Piratini	-28.72910	-50.4208	PA	eucalyptus and livestock	low, latifundia
2011	RK	Pinheiro Machado	-29.3562	-50.2208	PA	eucalyptus and livestock	low, latifundia
2011	PP	Herval	-29.4882	-50.3381	PA	eucalyptus and livestock	low, latifundia
2011	PP	Bagé	-29.665037	-55.20817	PA	eucalyptus, soya, and livestock	low, latifundia
2011	PP	Bagé	-29.66503	-49.20817	PA	eucalyptus, soya, and livestock	low, latifundia
2011	CT	Muitos Capões	-30.49141	54.98310	AF	landscape and forest fragmentation, with Araucaria forest altered by soy planting	low, latifundia
2011	DO	Bom Jesus	-29.44003	-55.41661	AF	natural rocky grassland and Araucaria forest fragment used extensively for livestock and planting *Pinus*	low, latifundia
2011	CT	Bom Jesus	-31.77767	-52.59165	AF	natural rocky grassland and Araucaria forest fragment used extensively for livestock and planting *Pinus*	low, latifundia
2012	DO	Bom Jesus	-30.6038	-55.0952	AF	livestock and *Pinus*	low, latifundia
2012	PP	Bom Jesus	-29.9625	-55.3538	AF	livestock and *Pinus*	low, latifundia
2012	PP	Hulha Negra	-30.49090	-48.98260	PA	eucalyptus, livestock, rice, and soya	low, latifundia
2012	RK	São Sepé	-31.18200	-54.0751	PA	landscape and forest fragments changed by livestock and soy planting	high, minifundios
2012	CT	Santo Antônio da Patrulha	-30.6961	-55.52188	AF /PA	landscape and forest fragments altered by planting rice	low, latifundia
2012	HU	Nova Roma do Sul	-29.5925	-50.1788	AF	forest fragment on hillside modified by viticulture	low, latifundia
2013	HU	Rosário do Sul	-32.103349	-53.10558	PA	natural rocky grassland and forest fragment used extensively for livestock and planting *Eucalyptus*	low, latifundia
2013	HU	São Sepé	-30.97692	-53.05377	PA	landscape and forest fragments changed by livestock and soy planting	high, minifundios, and urbanization

test points, model sensitivity was 100%, and all the test points positioned in the potential distribution area (Fig. 1).

DISCUSSION

Ecological niche modeling results (Fig. 2) showed the areas most ecological and geographic suitable for *C. tatouay* were associated with the two main mountainous areas of Rio Grande do Sul State, and the valley between them. In our model the areas with highest scores were Serra Geral in northeastern (with altitudes of 700 – 1400 m), "Serra do Sudeste" in southeast, and the "Planície Central", a relatively flat area, between these two montainous regions (Fig. 2). Gallery forests appear to be strongly linked with *C. tatouay* presence, especially when associated with areas o rock-rich natural grasslands. However, even disturbed areas with farming and the extensive cultivation of soya, rice, or exotic trees were used by the greater naked-tailed armadillo. In the generated ecological niche model, the most important variables for determining *C. tatouay* presence were average annual temperature (responsible for 52.3% of the variance), and precipitation in driest month (28.3%). These variables were similar to other models for the species, like presented by Abba *et al.* (2012) and Coitiño *et al.* (2013).

Because of the heterogeneity of sampling methods, it is impossible to fully quantify the expended sampling effort. However, it is possible to we are confident that the absence of records in north-northwest portion of the state reflects, if not absence, low densities of this species. There were also no records of *C. tatouay* in pioneer formations under marine influence in the east. However, it is interesting to note that 67.5% of our records came from Pampas region, a biome that the species is not considered to prefer (Anacleto *et al.*, 2006). We present here more records of *C. tatouay* for Pampas region than Anacleto *et al.* (2006) for all Brazil. Exactly why this is so requires further consideration, since the species seems genuinely uncommon in Pampas landscapes in neighboring Argentina and Uruguay (Abba *et al.*, 2012; Coitiño *et al.*, 2013).

Approximately 12.5% of the records came from roadkill. While this demonstrates that highways may be a threat to the conservation of *C. tatouay.* The extent of this impact cannot currently be measured, because of the lack of systematic sampling targeted at locations where roadkill was confirmed. Although the available studies on this subject are scarce and have not reported *C. tatouay* (Rosa & Mahus, 2004; Tumeleiro *et al.*, 2006; Hengemühle & Cademartori, 2008), Fontana *et al.* (2003) listed roadkill as the direct cause of population decline of 2.5% of the species of conservation interest in RS. Indeed the frequency of roadkill may be higher than estimated here, since many animals survive the initial impact only to die concealed in vegetation a few meters from the road. Moreover, unless surveys are frequent, roadkill frequencies may be underestimated because of scavengers: at least some of which are human (on one occasion, a local habitant asked for the carcass while we were examining it). In combination, this shows the need for urgent action by the licensing agencies in Rio Grande do Sul state to implement existing

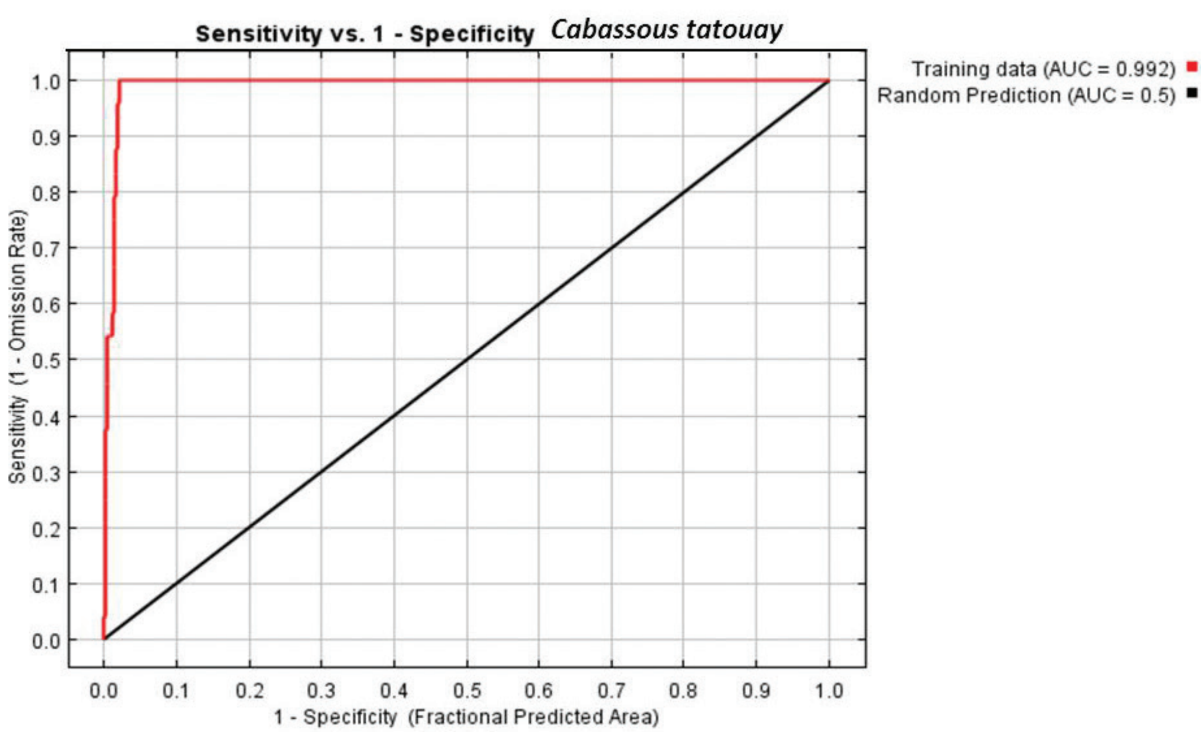

Fig. 1. Area Under the Curve produced by the Maxent algorithm, plus sensitivity and specificity response of the ecological niche model for *Cabassous tatouay* Desmarest, 1804 for the State of Rio Grande do Sul, Brazil.

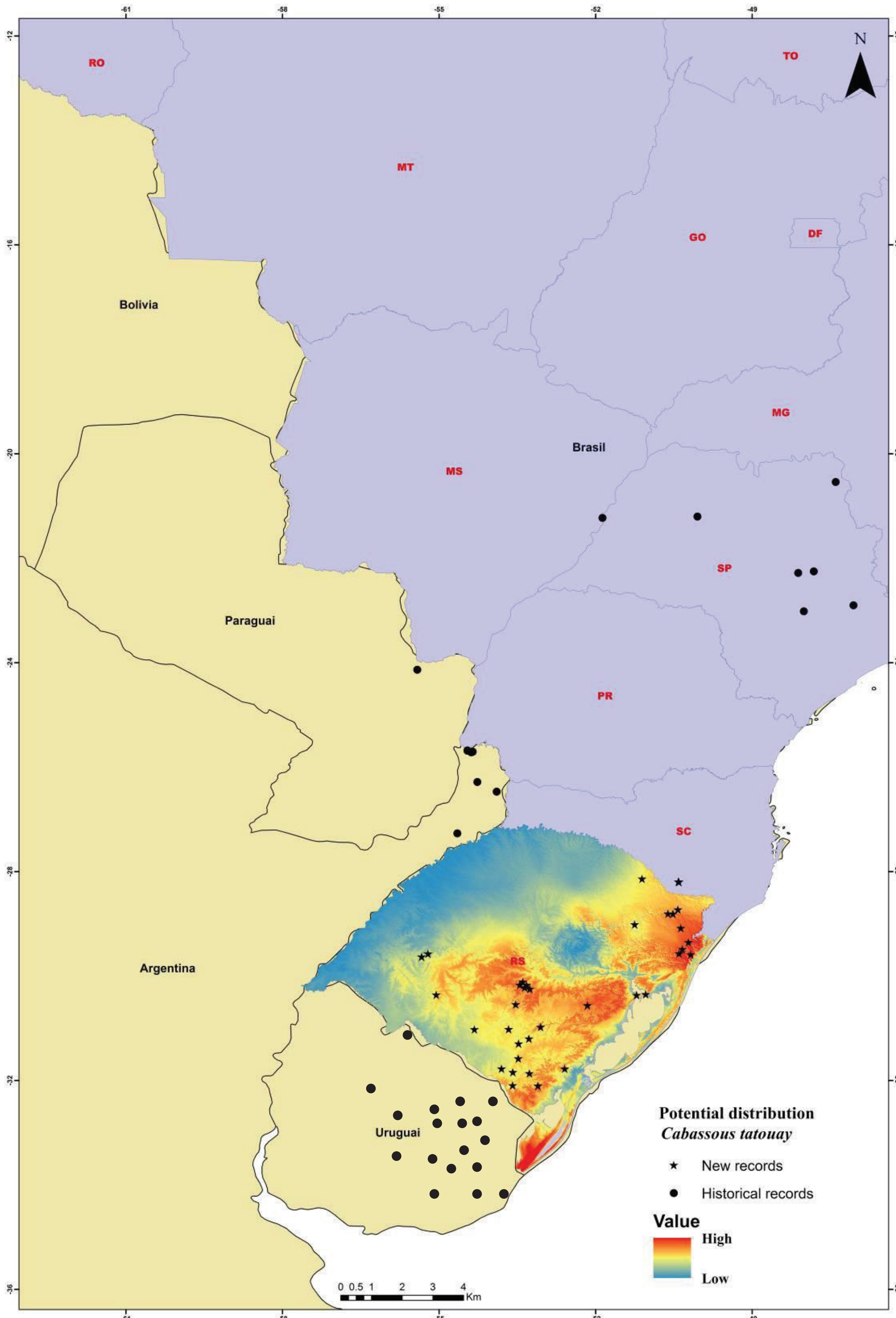

Fig. 2. Model ecological niche of *Cabassous tatouay* Desmarest, 1804 produced by Maxent algorithm, and a visualization of its potential distribution in the state of Rio Grande do Sul, Brazil. Stars indicate new locality records for the species, circles indicate historical records to the present study within South America.

regulations on the construction of highways in manners that mitigate and minimize the potential for vehicle-related deaths in wildlife living in proximity to highways, and to do this for both existing highways and those under construction or undergoing widening or expansion.

About 22% of records were obtained from local hunters, confirming the data of Peters *et al.* (2011), who reported Dasypodidae to be one of the mammalian groups most impacted by hunting in southwestern RS. Although illegal, this activity is driven by the consumption of meat, armadillo hunting is not the results of nutritional need, but instead is a recreational and cultural practice. As the naked-tailed armadillo is the largest species of armadillo, found in the RS, it is preferred over smaller species such as *Dasypus novemcinctus* Linnaeus, 1758, *Dasypus hybridus* Desmarest, 1804, and *Euphractus sexcinctus* Linnaeus, 1758.

The records collected in the current study, are insufficient to estimate population trends for *C. tatouay*. However, it is possible to say that *C. tatouay* can currently be considered one of the rarest species of mid-size mammal in RS. Other species of armadillo are easily recorded as roadkill, and by direct observations and camera traps. When compared with the number of records obtained during the study of other Cingulata and of species from other groups of mid-sized mammals considered as endangered (such as carnivores), it is likely that *C. tatouay* is now under the threat of regional extinction in RS state. Therefore, it is suggested that conservation actions be directed at *C. tatouay*, especially in regions indicated as having high ecological and geographical suitability for the species. These actions could involve: the creation of local of field stations or nature parks that have armadillo protection as their prime focus; the implementation of wildlife-friendly construction for existing and new highways; active counter-hunting surveillance; enforcement of existing legislation; and encouraging future studies that monitor *C. tatouay* population trends in RS (as well other areas within its natural range).

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