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Galictis cuja (Mammalia): An update of current knowledge and geographic distribution

Daniela A. Poo-Muñoz[1], Luis E. Escobar[1,2], A. Townsend Peterson[3], Francisca Astorga[1], John F. Organ[4] & Gonzalo Medina-Vogel[1]

1. Facultad de Ecología y Recursos Naturales, Universidad Andres Bello, Av. República 252, Santiago, Chile. (dapoom@gmail.com; ecoguate2003@gmail.com; fran.astorga@gmail.com; corresponding author: gmedina@unab.cl)
2. Center for Global Health and Translational Science, Department of Immunology and Microbiology, State University of New York, Upstate Medical University, Syracuse, NY, USA.
3. Biodiversity Institute, University of Kansas, 1345 Jayhawk Blvd. Lawrence 66045, Kansas, USA. (town@ku.edu)
4. U.S. Fish and Wildlife Service, 300 Westgate Center Drive Hadley and Department of Environmental Conservation, Holdsworth Natural Resources Center, University of Massachusetts, Amherst, MA 01003, USA. (john_organ@fws.gov)

ABSTRACT. The lesser grison (*Galictis cuja*) is one of the least-known mustelids in the Neotropics, despite its broad range across South America. This study aimed to explore current knowledge of the distribution of the species to identify gaps in knowledge and anticipate its full geographic distribution. Eighty-nine articles have mentioned *G. cuja* since 1969, but only 13 focused on the species. We generated a detailed model of the species' potential distribution that validated previous maps, but with improved detail, supporting previous southernmost records, and providing a means of identifying priority sites for conservation and management of the species.

KEYWORDS. Biodiversity conservation, Mustelidae, Neotropics, distribution, ecological niche modeling.

RESUMEN. *Galictis cuja* (Mammalia): Actualización sobre su conocimiento y distribución geográfica. El hurón menor (*Galictis cuja*) es uno de los mustélidos menos conocidos en el Neotrópico, a pesar de su amplia área de distribución a través de América del Sur. El objetivo de este estudio fue explorar la información actual de ocurrencias de la especie para identificar vacíos sobre su conocimiento y anticipar su distribución geográfica. Ochenta y nueve artículos han hecho referencia a *G. cuja* desde el año 1969, pero sólo 13 se enfocaron en la especie. Se generó un modelo detallado de la distribución potencial de la especie que validó mapas anteriores, pero con mayor detalle, apoyando previos registros australes, y proporcionando una herramienta para la identificación de sitios prioritarios para la conservación y manejo de la especie.

PALABRAS-CLAVE. Conservación de biodiversidad, Mustelidae, Neotrópico, distribución, modelamiento de nicho ecológico.

The lesser grison [*Galictis cuja* (Molina, 1782)] is one of the least-known mustelids of South America, and its natural history and conservation status remain poorly understood (Redford & Eisenberg, 1992; Yensen & Tarifa, 2003). It is perhaps typical of a mustelid in diet, eating small mammals (Ebensperger *et al.*, 1991; Diuk-Wasser & Cassini, 1998; Delibes *et al.*, 2003; Kraus & Rödel, 2004), and occasionally eggs, birds, reptiles, and amphibians (Yensen & Tarifa, 2003). It has a broad distribution across South America: southern Peru, western Bolivia, central and southern Chile, Paraguay, Uruguay, Argentina, and southeastern Brazil (Yensen & Tarifa, 2003; Borndholdt *et al.*, 2013), at elevations from sea level to 4200 m (Nabte *et al*., 2009), and including habitats from Atlantic forest (Rocha-Mendes *et al.*, 2010), and cold steppe in Patagonia (Prevosti & Travaini, 2005) to exotic forest plantations in Chile (Zúñiga *et al*., 2009). However, it appears to be rare in all habitats, as reflected in the low frequency of records (Santos *et al.*, 2004; Kasper *et al.*, 2007; Martínez *et al*., 2008; Andrade-Núñez & Aide, 2010).

The species is listed by International Union for Conservation of Nature as Least Concern (Reid & Helgen, 2008), considering its wide distribution and no apparent major threats, in spite of the minimal natural history information, imprecise known distribution, and unknown population size (Reid & Helgen, 2008; Butchart & Bird, 2010). In fact, many species with poor baseline data may be facing similar conservation threats, increasing the urgency to generate specific and updated information (see discussions in Diamond, 1987).

Hence, characterizing the geographic distribution of a species quantitatively and in detail is essential for guiding and planning conservation efforts (Margules & Pressey, 2000). Rigorous distribution maps can be generated from ecological niche models using fragmentary available occurrence data from specimen records, observations, or reports in the literature (Siqueira *et al.*, 2009), appropriately set in the context of accessibility of areas to the species in question (Barve *et al*., 2011). Such maps can be used for identification of areas for long-term protection, and even priority sites for reintroductions (Margules & Pressey, 2000; Martínez-Meyer *et al.*, 2006). In this contribution, we explore existing distributional knowledge of *G. cuja* to determine gaps, and generate a detailed map of potential and known distributional areas.

MATERIALS AND METHODS

Literature review. In January-July 2013, we used the key words "*Galictis AND cuja*" to find published articles on three electronic databases: Thomson Institute for Scientific Information (ISI; www.isiknowledge.com) and PubMed (http://www.ncbi.nlm.nih.gov) as they provide access to the most comprehensive databases of citations, and the Scientific Electronic Library Online (SciELO, http://www.scielo.org), for its focus on articles from South America. For the latter, we used an algorithm proposed by Curioso (2008) to improve the search. We removed articles where *G. cuja* was mentioned only in references but not in text, and then selected articles were classified as specific articles (i.e., articles where *G. cuja* was the target species of research) versus non-specific articles (i.e., articles where *G. cuja* was not the focus, such as baseline studies and general mammal censuses).

Potential distribution map. To establish the potential distribution of *G. cuja*, we generated an ecological niche model following established approaches (Peterson *et al.*, 2011). Definition of the study area extent is crucial to accurate ecological niche models, and must be based on the dispersal ability of the species (Barve *et al*., 2011). Currently, no standard methodology exists that can be applied in diverse situations, but the general concept has been outlined (Barve *et al.*, 2011). Considering current gaps of knowledge of the distribution and home range of this species, we calculated the approximate mean distance between all peripheral occurrence points and the centroid of known occurrences (Fig. 1). This distance was used to create a buffer around occurrence points, we used this area as a hypothesis of the accessible area for the species (Fig. 1).

Considering the broad known range of the species (Yensen & Tarifa, 2003; Bornholdt *et al.*, 2013), we used climatic variables (0.16° resolution; Hijmans *et al.*, 2005) as a source of useful environmental information for niche modeling (Peterson *et al.*, 2011). Variables used were annual mean temperature, mean diurnal range, isothermality, temperature seasonality, maximum temperature of warmest month, minimal temperature of coldest month, temperature annual range, mean temperature of warmest quarter, mean temperature of coldest quarter, annual precipitation, precipitation of wettest month, precipitation of driest month, precipitation seasonality, precipitation of wettest quarter, and precipitation of driest quarter (Hijmans *et al.*, 2005). We performed a principal components analysis (PCA) to reduce intervariable correlations and overall numbers of environmental variables (Peterson *et al.*, 2011).

Occurrence data were drawn from two main sources: (i) data associated with natural history museum specimens and reported in VertNet (http://vertnet.org), Arctos (http://arctos.database.museum/home.cfm), and GBIF (http://data.gbif.org/welcome.htm); see Acknowledgments for full list of institutions; and (ii) coordinates reported in scientific articles on *G. cuja* occurrences that were documented with museum specimens (Prevosti & Travaini, 2005; Carrera *et al.*, 2012; Bornholdt *et al.*, 2013). Bornhodlt *et al.* (2013) did not derive from our systematic literature search, but was included because it provides an exhaustive taxonomic review of *G. cuja*, listing corroborated specimens. Occurrences were resampled to one per pixel on our environmental grids to avoid duplicating records.

Coordinates were divided in two groups for calibration and evaluation, based on four quadrants with similar numbers of points, using two quadrants for calibration and two for evaluation (Fig. 2). Model results were evaluated for predictive ability using a cumulative binomial test, considering proportional area predicted and numbers of evaluation points predicted correctly (Arboleda *et al.*, 2009; Peterson *et al.*, 2011). After evaluating models prediction, a final model was developed using all occurrences.

We used the software Maxent, version 3.3.3.k, to model the species' ecological niche, based on associations between known presences and environmental conditions (Phillips *et al.*, 2006). Specific settings were 1000 bootstrap replicates, random seed, and median of replicates (logistic) as output. Input data and model outputs were managed using ArcGIS version 9.3 (ESRI, Redlands, California, USA).

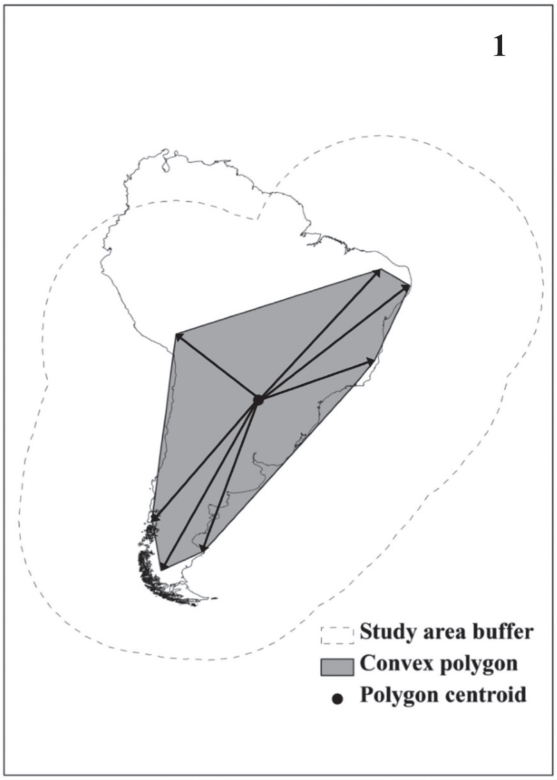
Considering that our data were of diverse provenance, an error tolerance of $E = 5\%$ was used to produce the binary map (Peterson *et al*., 2011). We visualized occurrences in environmental space by plotting temperature (°C) against precipitation (mm) for presences and the broader background across the accessible area; to characterize the background, we generated 3000 random points across the study area.

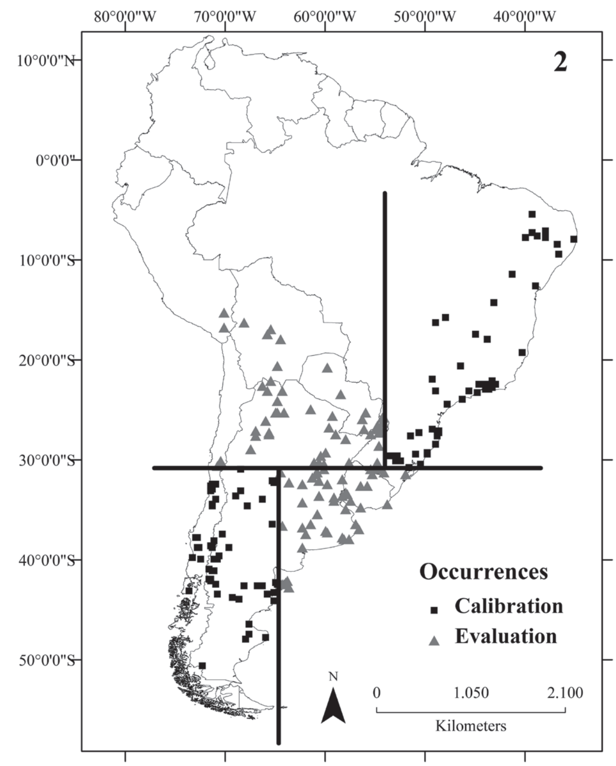
RESULTS

Overall, we obtained 84 articles from SciELO, 24 from ISI, and 8 from PubMed, totaling 116 articles. Eliminating articles in which *G. cuja* was only mentioned in references, and removing duplicate publications, 89 articles remained. We found 13 articles (14.6%) that had *G. cuja* as a focus. Number and type of articles (specific or non-specific to *G. cuja*) differed among countries, being Brazil producing most articles (41). Within specific articles, six articles were on diet, five on parasites or pathogens, and two documented species occurrences. The first article we found was published in 1969, followed by a gap between 1970 and 1989; then, a concentration of publications emerged between 2004 and 2013, averaging ~4 articles per year.

In our modeling exercise, the first 12 principal components (explaining >99.9% of total variance) were used as environmental variables. We found 354 occurrences of *G. cuja*; eliminating duplicates and resampling to pixel size of climatic layers, 201 unique occurrences remained. Model evaluation indicated significant predictive power to anticipate suitability in independent evaluation areas ($p < 0.001$; Fig. 2).

The final ecological niche model showed suitable areas in Ecuador (small areas in southern Guayas), Peru (southern Puno and northeastern Arequipa), eastern Brazil (fragmented, between Paraiba and Rio Grande do Sul), central and southern Bolivia (between Santa Cruz and Tarija), eastern Paraguay (between Concepcion and Itapua), Uruguay, much of Argentina (from Salta to Santa Cruz, including eastern states), and Chile (Coquimbo to Aysen;





Figs 1, 2. Lesser Grison [*Galictis cuja* (Molina, 1782)] occurrence data: 1, study area definition, lines with arrows inside the minimum convex polygon illustrate distances measured from centroid to each vertex; the average distance was used to build a buffer as a hypothesis of the accessible area (dashed line); 2, evaluation (gray triangles) and calibration (black squares) points. Lines represent the four quadrants (i.e., two for calibration and two for evaluation).

Fig. 3). Visualizations in environmental space showed broad use of precipitation and temperature combinations by the species, ranging 1.9-27.4 °C of temperature and 83-3883 mm of precipitation (Fig. 4).

DISCUSSION

We noted a striking lack of research on *G. cuja* in some countries, with a total of three articles from all of Chile, Uruguay, Bolivia, Peru, and Paraguay. According to our model, Uruguay, Chile, and Argentina all hold broad distributional areas for the species, yet the species has gone unstudied (Fig. 3). Of the 89 articles, only 13 (14.6%) had *G. cuja* as target species, and were focused mainly on diet (Ebensperger *et al*., 1991; Diuk-Wasser & Cassini, 1998; Delibes *et al.*, 2003; Kraus & Rödel, 2004; Zapata *et al*., 2007; Sade *et al*., 2012). Diet studies were based on prey identification in scat, and concentrated in the southern part of the distribution of *G. cuja*, where the most common prey items were rabbits (*Oryctolagus cuniculus* Linnaeus, 1758) and hares (*Lepus europaeus* Pallas, 1778), emphasizing the species' potential role in controlling invasive species (Delibes *et al*., 2003; Zapata *et al*., 2007). Scat identification in all studies was based on morphological characteristics of feces and disposal sites (latrines, burrows), but none used additional tools (e.g., molecular typing) to confirm scat identity, a weakness because *G. cuja* may coexist with other terrestrial mustelids like *Lyncodon patagonicus* de Blainville, 1842 and *Neovison vison* Schreber, 1777 (Previtali *et al.*, 1998). Another difficulty in diet studies is that *G. cuja* builds latrines, often with contribution of scats by several individuals (Delibes *et al*., 2003), impeding study of individual diets. These difficulties can be addressed by collection of fresh scats and use of camera traps and molecular analysis (Farrell *et al.*, 2000), or via studies based on stomach contents of carcasses, considering the relatively frequent cases of road kills of the species (Pfeifer *et al*., 2008; Cáceres *et al*., 2010).

The second most frequent topic was pathogens and parasites (Ferriolli & Barretto, 1969; Barros *et al*., 1990; Vieira *et al*., 2012; Zabott *et al*., 2012; Megid *et al*., 2013). Most of these articles were based on necropsy findings (Barros *et al*., 1990; Vieira *et al*., 2012; Zabott *et al*., 2012; Megid *et al*., 2013). One of the organisms studied was the zoonotic giant kidney worm *Dioctophyma renale* (Barros *et al*., 1990; Zabott *et al*., 2012), which appears to be hosted in South America by native species *G. cuja* and *G. vittata*, and eventually by the exotic *N. vison* (Measures, 2001). Also, a domestic dog strain of Canine Distemper virus (CDV) was detected in one individual (Megid *et al.*, 2013). These finding could be of conservation concern because CDV has been related with high mortality rates in mustelids, and can be transmitted by free-ranging dogs, an increasing issue in some South American countries (Acosta-Jamett *et al.*, 2011; Megid *et al.*, 2013). We did not find specific studies on threats to *G. cuja*, such as land

Fig. 3. Potential distribution model for *Galictis cuja* (Molina, 1782) visualized across South America (in gray).

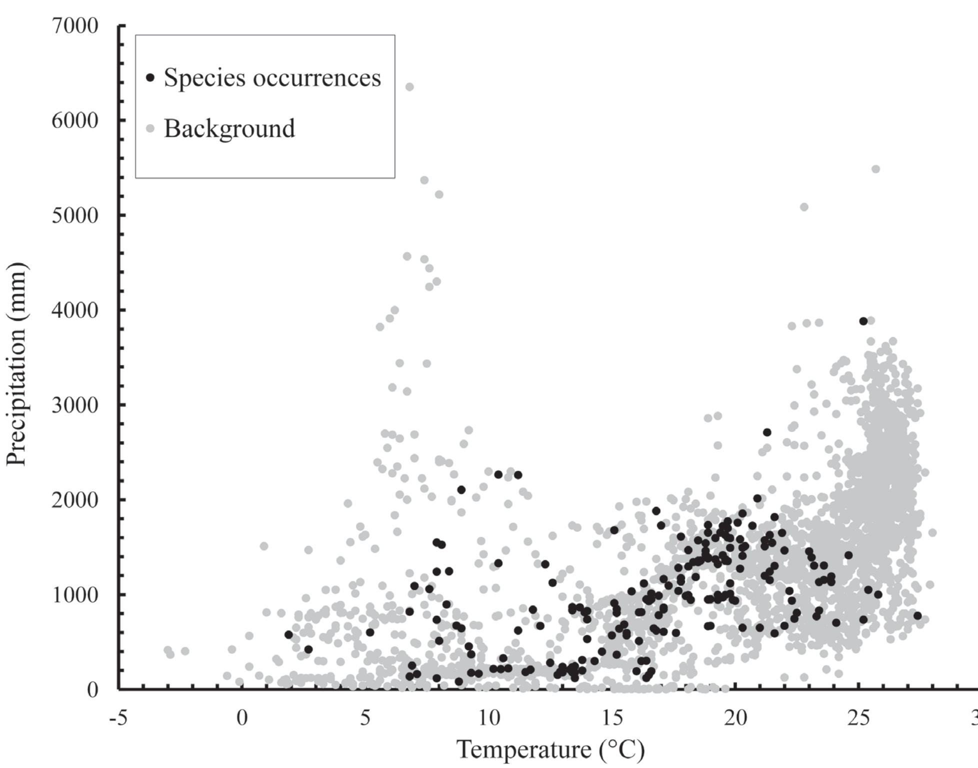


Fig. 4. *Galictis cuja* (Molina, 1782) occurrences (black points) in a two-dimensional environmental space. Background (gray points) represents environments across the study area.

use change, human encroachment, or invasive species. No articles concerning the species' abundance or populations were found.

Previous range maps of *G. cuja* may be underestimating the species distributional potential in some areas. As an example, previous estimates of the species' distributional area in Chile were 252,300 km^2 (Cofré & Marquet, 1999), while our model estimated >310,000 km^2. We reviewed three previous distribution maps for *G. cuja.* The smallest was from IUCN (Reid & Helgen, 2008), while Prevosti & Travaini (2005) and Yensen & Tarifa (2003) presented broader distribution maps, the former including occurrences in southern South America, based on skin and skeletal remains. Our map anticipated the potential for these southern occurrences, validating the southern range limit of the species proposed by Prevosti & Travaini (2005; Fig. 3).

Finally, to improve *G. cuja* conservation, further research should address movement patterns, phylogeography, and emerging threats such as effects of invasive species, to understand critical aspects of its ecology that are not presently well understood. Exploration of these topics would offer a robust baseline by which to identify and monitor current status of and emerging threats for the species.

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