Nature Conservation 48: 57–81 (2022)
doi: 10.3897/natureconservation.48.77722
https://natureconservation.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
Nature Conservation
Launched to accelerate biodiversity conservation

Not only range, but quality: human influence and protected areas within the distribution of mammal species subject to use in the Department of Cundinamarca, Colombia

Lizeth Aguirre Sierra[1], Diego A. Zárrate-Charry[1,3], Leonardo Lemus-Mejía[1], Jessica Morales-Perdomo[2], José F. González-Maya[1,4]

1 *Proyecto de Conservación de Aguas y Tierras – ProCAT Colombia/Internacional, Carrera 11 # 96-43, Of. 303, Bogotá, Colombia* **2** *Corporación Universitaria Minuto de Dios. Carrera 74#81c – 05, Bogotá, Colombia* **3** *Fondo Mundial para la Naturaleza, WWF Colombia, Carrera 10a # 69A-44, Bogotá, Colombia* **4** *Departamento de Ciencias Ambientales, CBS, Universidad Autónoma Metropolitana Unidad Lerma. Av. de las Garzas No. 10, Col. El Panteón. C.P, 52005, Lerma de Villada, Estado de México, Mexico*

Corresponding author: José F. González-Maya (jfgonzalezmaya@gmail.com)

Academic editor: W. Magnusson | Received 7 November 2021 | Accepted 7 February 2022 | Published 7 April 2022

http://zoobank.org/AD998F0C-A745-4109-BF04-D13BD7F6057B

Citation: Aguirre Sierra L, Zárrate-Charry DA, Lemus-Mejía L, Morales-Perdomo J, González-Maya JF (2022) Not only range, but quality: human influence and protected areas within the distribution of mammal species subject to use in the Department of Cundinamarca, Colombia. Nature Conservation 48: 57–81. https://doi.org/10.3897/natureconservation.48.77722

Abstract

Mammal conservation in transformed landscapes depends heavily on the role of protected areas, especially for species used by local communities both within and around these areas. We evaluated the level of representation and the magnitude of the influence of humans, via human footprint, across the range of mammals used by local communities in the Department of Cundinamarca, Colombia. We emphasised the differences of the human influence at a department scale and inside Protected Areas (PA). The definition of species used by local communities refers to using a resource for its economic, religious and/or traditional value. Specifically, we addressed whether there is a difference between the magnitude of human influence inside and outside the PAs and if the impact is greater on threatened species, species with greater or lesser representation or according to their use. We found 43 species subject to use in our analysis, with low values of representation when compared with global targets ($\bar{X}$ ± CD = 10.69% ± 4.99) and with high values of vulnerability, based on the mean value of the Spatial Human Footprint Index (HSFI) (57 ± 2.74). We found a difference of 10.72 points between the average HSFI of the Department and that of the PAs ($\bar{X}$ ± CD = 10.73 ± 5.98%). This shows that the status of each species' habitats is less impacted by human activities within PAs and that the conservation areas for all species depend largely on their presence in largely transformed landscapes. Although this seems an expected outcome, the Department of Cundinamarca is one of the less represented on PAs at a national level and has suffered from severe fragmentation; thus, our results highlight the need for improving and expanding the current PA system as most species, especially those subject to use, will depend on their existence for their conservation on the long run.

Keywords
Andes, human footprint, Protected Areas, species modelling, species range

Introduction

Mammals are one of the main groups widely used to assess landscapes and ecosystems' ecological integrity and health in different parts of the world (Rondinini et al. 2011; González-Maya et al. 2015; Di Minin et al. 2016; González-Maya et al. 2016). This largely responds to their role in the functioning and maintenance of ecosystems, which supports its use for conducting conservation status assessments (Aubry et al. 2003; Prugh et al. 2009; Ripple et al. 2014). Mammals stand out for their ability and capacity to disperse seeds, maintain the balance of trophic chains and their role as soil fertilisers and pollinators, amongst many others (Aubry et al. 2003; Noss et al. 2012; Lacher et al. 2019). Likewise, they have been widely used to understand protected areas (PA) status, connectivity and conservation contribution, particularly when analysing at landscape scales (Beier 1993; Cullen et al. 2013; Zárrate-Charry et al. 2018).

Even when mammal species provide a diversity of ecosystem services, they are one of the most threatened taxonomic groups globally due to the loss of their habitat, overexploitation, climate change among others (Schipper et al. 2008). These pressures, that overall affect biodiversity in general, are considered severe for many mammals since most of them have high energy requirements, usually depending on quality habitats and abundant resources (Schipper et al. 2008; Ripple et al. 2014); although some species might tolerate certain levels of intervention, overall, mammals require habitats and resources which in general make them good ecological indicators (Sinclair 2003; Schipper et al. 2008; Pineda-Guerrero et al. 2015; González-Maya et al. 2017). In addition to being one of the most important groups of animals for most ecosystems, mammals are also one of the groups most directly used by human communities (Cortés-Gregorio et al. 2013; Ripple et al. 2014; Van Vliet et al. 2015). From a sociocultural perspective, they are not only a tangible resource, object of appropriation and the basis of various recreational, cultural and subsistence needs, but they are also part of the collective imagination of intangible forms, whether associated with myths, legends, art or folklore, even contributing to the identity of various peoples and communities (Vargas-Clavijo 2008; Vargas-Clavijo 2009).

Along with the many strategies for mammal conservation, various management actions have been designed, ranging from conservation plans (Castaño-Uribe et al. 2013; Ministerio del Ambiente and Wildlife Conservation Society 2014), strategies for sustainable use of species or landscapes (Fischer et al. 2010; Sims and Alix-Garcia 2017) and strategies for landscape conservation, for which Protected Areas (PAs) continue to be one of the main pillars (Stolton and Dudley 2010; González-Maya et al. 2015; Di Minin et al. 2016; Zárrate-Charry et al. 2022). PAs are an essential tool for ensuring the natural and cultural heritage of a country (Sánchez-Azofeifa et al. 1999; Forero-Medina and Joppa 2010), and these protected landscapes aim at safeguarding both natural and cultural elements that are representative of a particular region (Davey 1998; Loucks et al. 2008; Forero-Medina and Joppa 2010; Roncancio-Duque and Vélez Vanegas 2019). Previous efforts have contributed to recognising that PAs play an important role in maintaining patterns of land use and biodiversity, which contributes to social aspects and in the preservation of various species and cultural characteristics (Olmos Martínez et al. 2013); PAs are critical for the provision of environmental goods and services, while safeguarding critical habitats for the maintenance of species (Armsworth et al. 2007; Luck et al. 2009; Ferraro et al. 2011).

Colombia is considered the sixth country with the highest mammal richness worldwide, with about 530 species (Ramírez-Chaves et al. 2019). Of these, 236 species are confirmed for the Cundinamarca Department (Lemus-Mejía 2021). Despite this large number of mammal species, there is minimal information on integrating these species into the different management plans or conservation strategies applied in the areas set aside for this purpose (Sánchez et al. 2004). PAs and the landscapes in which they are located, have been affected in recent decades by the increase of various stressors that directly affect biodiversity. Some of the main stressors identified for Colombia include deforestation, agriculture, poaching, presence of exotic invasive species, among others (Parques Nacionales Naturales de Colombia 2021); all these have a great effect on biodiversity and are now included as targets and priorities in different plans for their mitigation. At the national level, about 9.6% of the total area of the National System of Protected Areas (**SINAP**) has been transformed (IDEAM et al. 2017). This, coupled with the increasing rate of deforestation (Clerici et al. 2020), seriously affects the ecological processes on which species and ecosystems depend. Added to this, pressures associated with the drivers of global change, such as the unsustainable use of natural resources, the increase in the presence and abundance of invasive species and the challenges imposed by climate change, seriously affect the habitats of most species (Guerra et al. 2019; Clerici et al. 2020; Harfoot et al. 2021; Murillo-Sandoval et al. 2021). Likewise, the direct pressures generated by the increasing use of resources and territory, due to accelerated demographic growth, generate the expansion of more urban areas (Alberti and Marzluff 2004; Etter et al. 2008; Curtis et al. 2018), reflecting on the intensity generated by the anthropogenic impact on terrestrial ecosystems where the human contribution is increasing (Sanderson et al. 2002; Correa Ayram et al. 2020).

This trend, associated with the increase in biodiversity loss stressors, generates an urgency for the conservation and management of species and their habitats, especially those subject to direct use (Bogoni et al. 2020; Green et al. 2020; Nickel et al. 2020). To better design management and conservation strategies for species, it is vital to understand the potential effect that the transformation of ecosystems and human actions has on the habitats and distribution areas of the species (Bogoni et al. 2020). Correa Ayram et al. (2020), through the multitemporal analysis of the Human Spatial Footprint Index (a measure that assesses the human impact on ecosystems derived from multiple variables), managed to identify that, in the last 45 years, the impact, or the magnitude of the human footprint, has increased by 50% in Colombia, with the Caribbean and the Andes being the regions where this increase has been greater. Likewise, they evaluated the future trend and predicted that, if there is no change in the pattern of use, by the year 2030, the Human Spatial Footprint Index will have increased by 12% more. In addition, approximately 65% of the land has already been subject of transformation processes (Correa Ayram et al. 2020). Specifically for the Andean Region, current values of the HSFI are estimated as high (Fig. 1A) and this has reflected on decreasing wealth of local or regional fauna (Etter and van Wyngaarden 2000; Etter et al. 2006) and triggered concentration of species populations to the small vegetation fragments that remain relatively intact (Armenteras et al. 2003; Cortés-Delgado and Pérez-Torres 2011; Magioli et al. 2021).

Here, we evaluated the representation of mammals in PAs and the magnitude of the human influence over the range of mammal species subject to use in the Cundinamarca Department and whether this influence is less significant within PAs. For this purpose, we developed three specific objectives: i) to analyse the representation of mammal species subject to use within the current PAs system, ii) to evaluate the magnitude of human influence, using the Human Spatial Footprint Index (HSFI) approach, across the range of all mammals subject to use inside and outside PAs and iii) to identify differences in the magnitude of human influence according to representation and different level of threat.

Materials and methods

Study area

The study area comprised the Cundinamarca Department (political division homologous to states), located in central Colombia, in the Andean Region (Fig. 1). Cundinamarca is the most populated Department in Colombia and includes the country's capital city. The Department has an average altitude of 3,341 m a.s.l., a total area of 24,210 km^2 distributed in 116 municipalities with 2,919,060 inhabitants without considering the capital city's population (7,743,955 inhabitants) (DANE 2019). Being one of the most populated regions also presents one of the highest levels of transformation (Fig. 1A). The Department includes 184 protected areas distributed in 73 of the national or regional level and 111 private reserves of the civil society, covering 315,894.45 hectares; many of these areas are very small (mean area of 41.6 ha) and scattered through the Department (RUNAP 2019) (Fig. 1B).

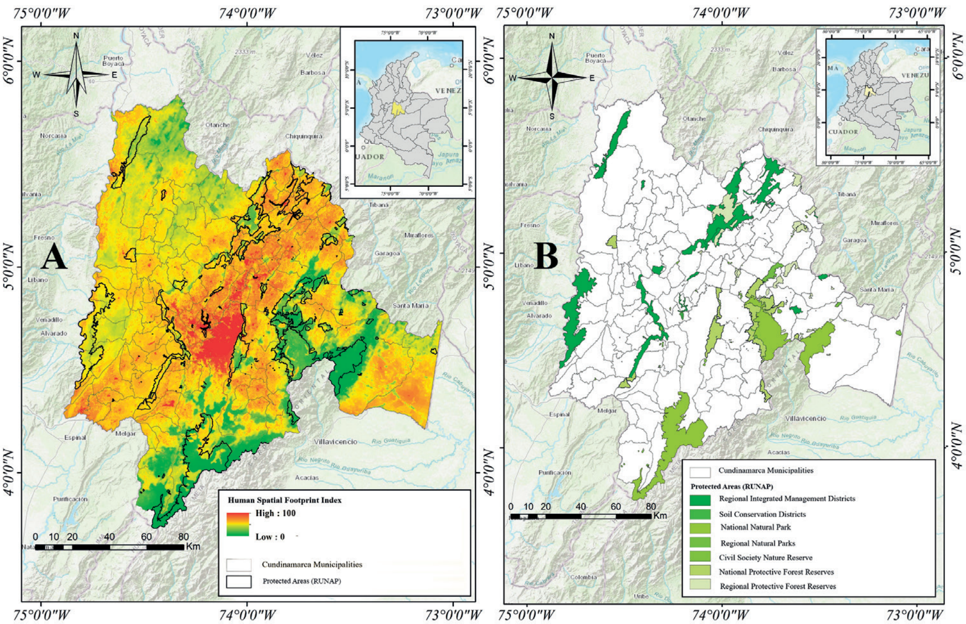

Figure 1. Human Footprint and Protected areas in Cundinamarca **A** representation of the Human Spatial Footprint Index and **B** location of Protected Areas in the Department of Cundinamarca, Colombia. PA categories are based on the national classification.

Species selection

In our study, we analysed the current human influence within the potential distribution range of mammal species used by local communities. The definition of species used by local communities refers to using a resource for economic, religious and traditional values governed by social, cultural and economic trends (Racero-Casarrubia et al. 2008; Cunha-Ribeiro and Schiavetty 2009). These species are used as the study object because they can generate, in the short term, a greater impact on the well-being of local communities; if their abundance or presence is affected, it will have a direct effect on ecosystems and their services, thus affecting human well-being. For all species confirmed in the Department (González-Maya et al. 2021b; Lemus-Mejía 2021), we conducted a bibliographic search for their potential social and cultural uses worldwide (e.g. food, medicine, economy, religion and others). Specifically, we searched for all reported uses on multiple databases, including the IUCN Red List of Threatened Species (IUCN 2018) and complemented with local and regional literature available on multiple databases (i.e. Google Scholar, Web of Science, SCOPUS, among others.). We used Boolean operators (AND, OR and NOT) creating different searching equations that combine the colloquial and scientific name of each species with words, such as "Food", "Pet", "Control", "Subproducts", "Medicine" and any synonym of these words that may lead to finding information about the possible uses of the species. This first literature search was a basic approximation to make the first filter on the species that were considered as subject of use. Complementarily, we conducted interviews across the Department to survey potential uses for the entire species list. The interviewed people were from 20 municipalities of the Department, all identified as areas of high vulnerability due to presence of forest remnants and high species richness combined with high levels of human transformation. We conducted a semi-structured interview including a visual guide of species potentially present in the area and the different types of uses (Barbosa Camargo 2020), amongst other questions related to the perception of changes in their abundance, conflict, amongst others. In order to characterise the type of use or value that communities give to each species, we interviewed about the type of relationship that each interviewee considered to have with each of these species. The relationship could vary from conflict events and retaliatory killing to direct consumption, commercialisation, use of it as products, medicine, contemplation or any other cultural relationship (Castaño-Uribe et al. 2013; Ministerio de Ambiente y Desarrollo Sostenible and Fundación Omacha 2016; Tinoco-Sotomayor et al. 2021).

To secure a representative sample size, we defined the number of interviews for each locality according to the extension of each municipality and the human population census for 2018 (DANE 2019). Based on the corresponding number of interviews for each municipality, we identified cells with forest assuming the presence of wildlife and the potential use by the communities; thus, we located core areas where we conducted the interviews. From February to March 2020, we conducted 200 interviews in over 120 villages of 20 prioritised municipalities and to people ranging between 15 and 70 years of age and with at least six months of residence in the area.

We then categorised each mammal species according to four use categories: Food, defined as any direct consumption of a mammal; Pet/Traffic, defined as any report of direct use as a pet or subject to illegal traffic for multiple purposes; Control, defined as those species subject to retaliatory killing, usually due to previous conflict or considered as a "pest" and; Subproducts, defined as those species used whole or their parts for the production of a secondary product (Osbahr and Morales 2012; Castaño-Uribe et al. 2013; Barbosa Camargo 2020). Furthermore, we categorised each species according to its international conservation status, following the IUCN Red List of Threatened Species Categories and Criteria (Critically Endangered (**CR**), Endangered (**EN**), Vulnerable (**VU**), Near Threatened (**NT**), Least Concern (**LC**), Data Deficient (**DD**) or Not Evaluated (**NE**)).

Potential distribution and representation

We estimated representation as the percentage of potential distribution, or range extension, of a species that is currently protected or included by existing PAs (González-Maya et al. 2015; House et al. 2017). In order to have a range for each species, we based our analysis on models for all species (González-Maya et al. 2021b; Lemus-Mejía 2021), based on an ecological niche modelling approach (Peterson et al. 2011). In order to create distribution models for all species, we constructed a database composed of historical and current records for the 236 mammalian species confirmed for the Department of Cundinamarca (González-Maya et al. 2021b; Lemus-Mejía 2021); records were obtained from different sources, such as biological collections and published and grey scientific literature available in the country (Zárrate-Charry 2018; González-Maya et al. 2021b (i.e. SIB Colombia, VertNet, GBIF). To construct species distributions, we used the occurrence records that passed a quality filter and a spatial filter thinning, focusing our analysis on species with 20 or more records (Lemus-Mejía 2021), thus securing a better distribution hypothesis. We used a set of bioclimatic variables (Fick and Hijmans 2017) with a 1 km^2 resolution: Bio1 (Annual Mean Temperature), Bio2 (Mean Diurnal Range), Bio4 (Temperature Seasonality), Bio12 (Annual Precipitation) and Bio15 (Precipitation Seasonality). The variables Bio13 (Precipitation of the Wettest Month), Bio14 (Precipitation of the Driest Month) and elevation (Instituto Geográfico Agustín Codazzi 2016) were additionally included since the first two could reflect the ENSO (El Niño-Southern Oscillation) phenomenon and the third is considered a proxy for variables, such as radiation and oxygen concentration (Burneo et al. 2009). We developed potential distribution models using RStudio Desktop 1.4.1106 (R Team Development Core 2019) and the Wallace package (Kass et al. 2018). Details on the modelling approach and the specific models constructed for our analyses are also available elsewhere (González-Maya et al. 2021b; Lemus-Mejía 2021). A total of 30 models for each species were created (Lemus-Mejía 2021) using six different values of Regularisation Multipliers (RM; 0.5–3 in intervals of 0.5), five Feature Classes (FC) combinations (linear = **L**, linear-quadratic = **LQ**, hinge = **H**, linear-quadratic-hinge = **LQH** and linear-quadratic-hinge-product = **LQHP**), with 10,000 background points. The best models for each species were selected from the AUC test and the AICc Delta value (Zárrate-Charry et al. 2018). We then compared the areas covered by the binary representation of the species distribution model with the most updated polygon of all PAs in the Department (RUNAP 2019). A representation value was estimated for each species, including the total area of the Department covered by the potential distribution and the percentage of the range included in PAs and, likewise, the average representation value of the total species within the Department. Additionally, we compared representation values for species categorised under any threat category and non-threatened species using a Mann Whitney U test. Furthermore, considering that different types of uses represent differential pressures for each species, according with the type of use, we compared the representation between types of uses and within each type of use using a Kruskal-Wallis non-parametric test.

Human influence on landscapes (Human Spatial Footprint Index-HSFI)

To evaluate the human influence over each mammal species subject to use, we used the most updated Human Spatial Footprint Index (HSFI) for the country with an accuracy of 300 m^2 (Correa Ayram et al. 2020). This Index shows a spatial representation of the cumulative impact that human pressures have on the environment (Venter et al. 2016). The human footprint measures directly, through spatial data, the impact on demand and consumption that humans have on Earth and human practices that are significantly reducing the resilience or recovery capacity of ecosystems causing irreversible effects on diversity, such as local extinction of species (Correa Ayram et al. 2017). The three dimensions assessed are soil intensity, time of anthropogenic intervention and biophysical vulnerability (Correa Ayram et al. 2020). This Index has been widely used to assess landscape changes and humans' potential impact on both species' habitat and connectivity (Nori et al. 2015; Correa Ayram et al. 2017). We overlapped the Human Spatial Footprint Index (**HSFI**) with the potential distribution areas of all species. This process allowed us to obtain a layer of values associated with the HSFI for each species, calculating a mean value and a standard deviation of the HSFI for each species for the whole Department. We then evaluated the mean value of the HSFI for the orders to identify potential groups that present a greater vulnerability due to the low quality of their distribution areas and due to the high values of human impacts. To evaluate the role that PAs can play for maintaining quality habitats for all species, we performed an evaluation of the mean value of the HSFI within the PA and contrasted these values with the total HSFI value of its distribution area; we used a t-paired test to explore if statistically significant differences existed between HSFI values in and out Protected Areas. This procedure also allowed obtaining a mean value (± SD) to understand the degree of human influence present in species distribution within PAs. The Human Spatial Footprint Index values are presented from 0 to 100, with 0 being the areas considered "natural" and 100 the areas with the maximum value of Human Footprint or anthropogenic impact (Correa Ayram et al. 2020). Finally, we compared the HSFI overall for the Department and within PAs between types of uses and within each type of use, using a Kruskal-Wallis non-parametric test.

All geographic analyses were performed using ArcGIS 10.x (Environmental Systems Research Institute 2016) and all statistical analyses were performed in R language (R Team Development Core 2021).

Results

We identified 43 species subject to use for the Department, mostly associated with direct use, but with some others related to cultural and religious uses (Table 1). Of the total 43 species subject to use in the Department, nine are threatened according to the IUCN Red List of Threatened Species and 10 are threatened according to the country's national legislation. Carnivora was the order with the highest number of species analysed with 16 (37.21%), followed by the order Primates with seven, Rodentia with six and Pilosa with five (16.28%, 13.95% and 11.63%, respectively; Table 1).

Distribution of species richness showed an important concentration of species for the lowlands bordering the Magdalena River, on the western flank of the eastern range of the Andes (Fig. 2). The mean value of representation within PAs for all species was lower than the global representation goals (17%; Aichi targets; Gannon et al. 2019) and, in general, is considered under most national goals (Mean ± SD = 10.69 ± 4.99%; Fig. 3).

Table 1. Mammals subject to use identified for the Department of Cundinamarca, Colombia, including the type of use reported.

Order	Species	Common name	IUCN Cat.	Use reported			
				Food	Pet/ Traffic	Control	Subproducts
Artiodactyla	*Mazama rufina*	Dwarf red brocket	VU	X		X	X
	Pecari tajacu	Collared peccary	LC	X	X	X	X
Carnivora	*Cerdocyon thous*	Crab-eating fox	LC				X
	Eira barbara	Tayra	LC			X	X
	Herpailurus yagouaroundi	Yaguarundi	LC		X	X	
	Leopardus pardalis	Ocelot	LC		X		X
	Leopardus tigrinus	Oncilla	VU		X		X
	Leopardus wiedii	Margay	NT		X		X
	Lontra longicaudis	Neotropical otter	NT			X	X
	Mustela frenata	Long-tailed weasel	LC				X
	Nasua nasua	South American coati	LC	X	X	X	X
	Nasuella olivacea	Western mountain coati	NT	X	X		X
	Panthera onca	Jaguar	NT	X	X	X	X
	Potos flavus	Kinkajou	LC	X	X		X
	Procyon cancrivorus	Crab-eating raccoon	LC		X		X
	Puma concolor	Puma	LC		X	X	X
	Tremarctos ornatus	Spectacled bear	VU	X	X		X
	Urocyon cinereoargenteus	Grey fox	LC		X	X	X
Chiroptera	*Desmodus rotundus*	Vampire bat	LC			X	X
	Myotis nigricans		LC			X	
Cingulata	*Dasypus novemcinctus*	Nine-banded armadillo	LC	X	X		X
	Cabassous centralis	Naked-tailed armadillo	LC	X			X
Didelphimorphia	*Caluromys lanatus*	Brown-eared woolly opossum	LC				X
	Chironectes minimus	Water opossum	LC				X
	Didelphis marsupialis	Common opossum	LC	X		X	X
Pilosa	*Bradypus variegatus*	Three-toed sloth	LC	X	X		X
	Choloepus hoffmanni	Hoffmann´s two-toed sloth	LC	X	X		
	Myrmecophaga tridactyla	Giant anteater	VU	X	X	X	X
	Tamandua mexicana	Northern tamandua	LC	X	X		
	Tamandua tetradactyla	Southern tamandua	LC			X	X
Primates	*Alouatta seniculus*	Colombian red howler monkey	LC	X			X
	Aotus griseimembra	Grey-handed night monkey	VU	X	X		
	Ateles belzebuth	White-bellied spider monkey	EN	X	X		
	Lagothrix lagotricha	Common woolly monkey	VU	X	X	X	X
	Saguinus leucopus	Silvery-brown tamarin	EN		X		
	Saimiri sciureus	Guianan squirrel monkey	LC		X		
	Sapajus apella	Black-capped capuchin	LC	X	X		
Rodentia	*Cavia aperea*	Brazilian guinea pig	LC	X			
	Cuniculus paca	Agouti	LC	X	X		
	Cuniculus taczanowskii	Mountain paca	NT	X		X	
	Dasyprocta fuliginosa	Black agouti	LC	X			
	Dasyprocta punctata	Central American agouti	LC	X			
	Hydrochoerus hydrochaeris	Capybara	LC	X	X	X	X

More than half of the species presented in the analysis have a representation value lower than 10%, with the rest of their ranges being outside PAs (Fig. 3). Orders with the lowest mean representation value are the order Pilosa and Didelphimorphia (Mean ± SD = 7.21 ± 4.44% and 7.626 ± 1.37%, respectively), while Carnivora and Artiodactyla showed the highest mean representativity (Mean ± SD = 13.61 ± 4.70% and 13.63 ± 9.92%, respectively). The order Pilosa contained the species with the lowest PA representation in the whole study, the anteater (*Tamandua tetradactyla*), a species that, besides being under-represented, has a very small distribution area in the jurisdiction of the Department.

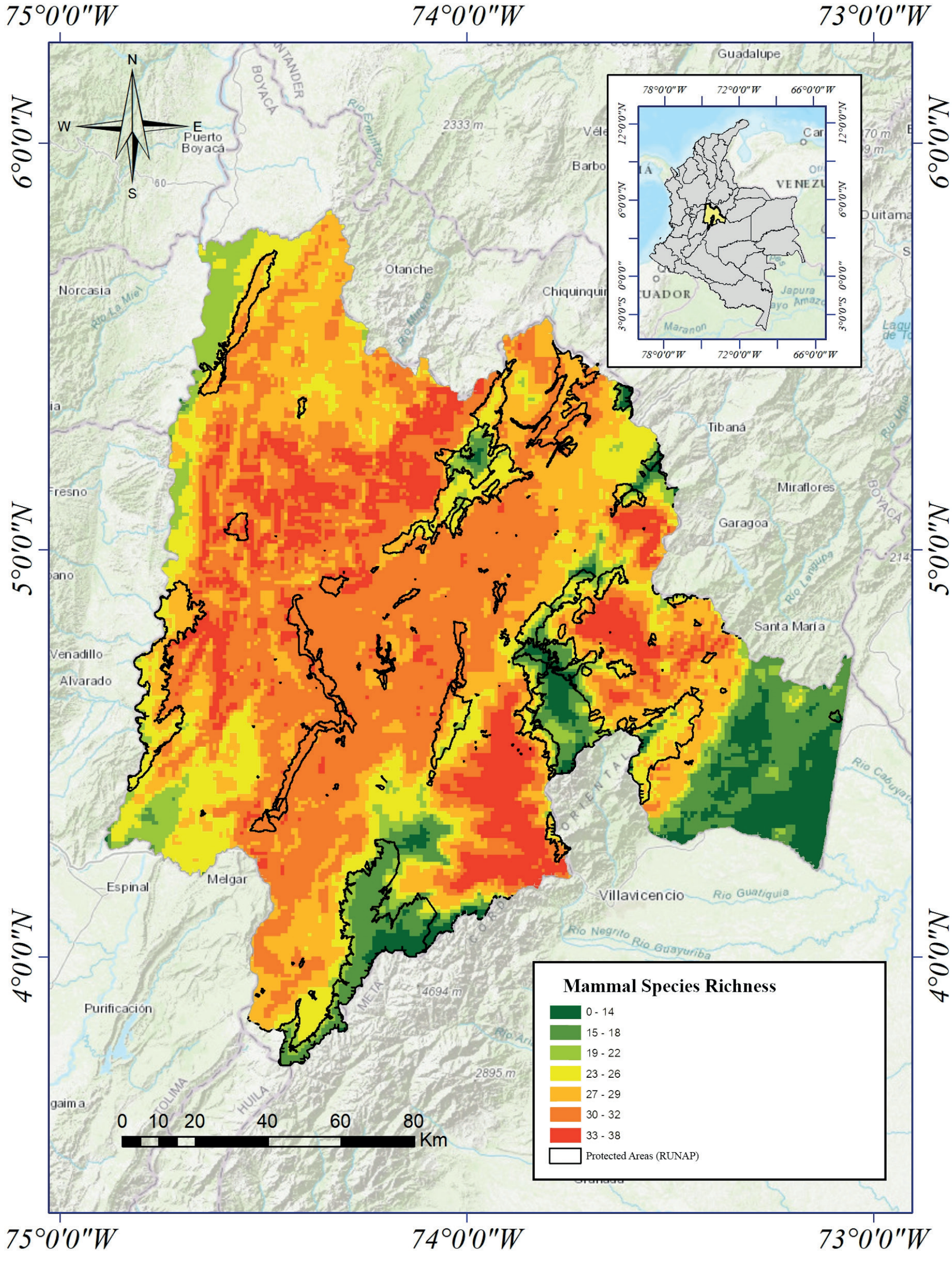

Figure 2. Mammal species richness. Potential distribution of species richness of mammals subject to use in the Department of Cundinamarca, Colombia, with a resolution of 1 km.

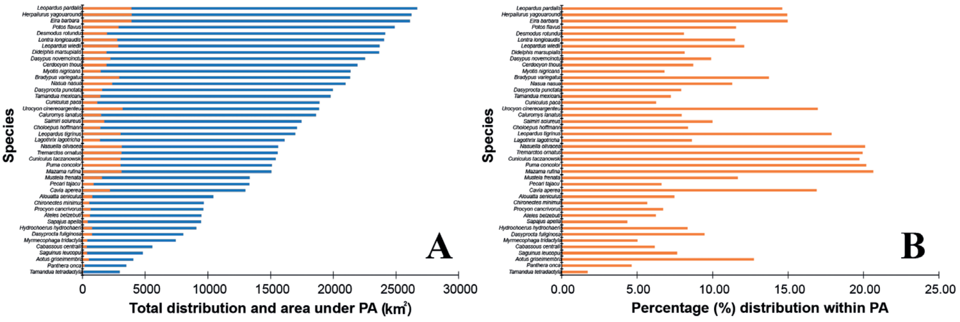

Figure 3. Distribution and representation of mammals in PAs **A** Total distribution and area under Protected Areas values and **B** representation (%) within PAs for all mammal species subject to use in the Department of Cundinamarca, Colombia.

In terms of species under any risk category, mean representation was significantly lower than for the non-threatened species (69.91 vs. 46.19%; W = 105.00, p = 0.026). Of these species, the Jaguar (*Panthera onca*) has the lowest representation for the Department (4.64%). The mean value (± SD) of the Human Spatial Footprint Index (HSFI) for the distribution areas of all species was 57.08 (± 2.74). This is a medium value, but it is very close to values considered high according to the HSFI, which are those over 60. We found very few species with areas with HSFI values lower than 40, which means that there are no areas that could be considered with low footprint values (Fig. 4).

Although for most of the Department of Cundinamarca, HSFI values are high or medium, within the PAs, the values are lower, which is evident in PAs such as

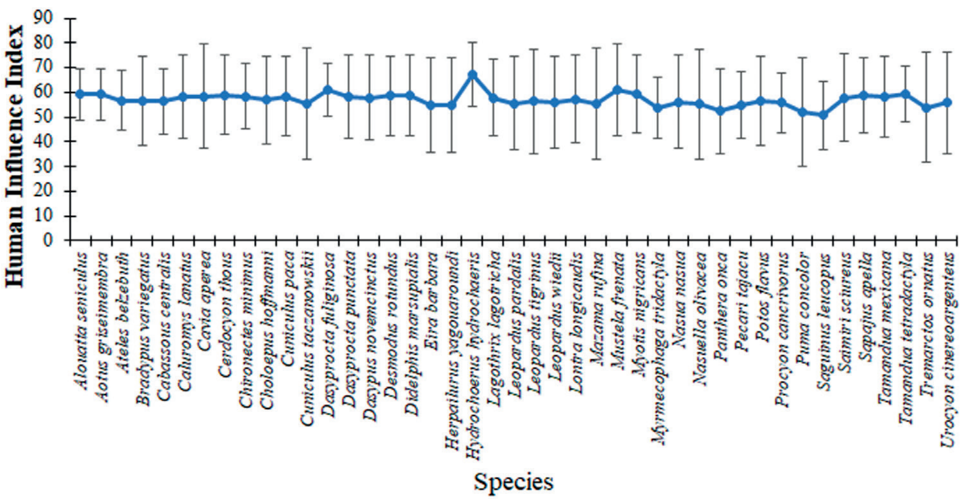

Figure 4. Mean Human Spatial Footprint Index within mammal ranges. Distribution and mean value of the Human Spatial Footprint Index (HSFI) for mammal species subject to use within the Department of Cundinamarca, Colombia.

Chingaza National Natural Park, the Cuchillas Negra and Guanaque and Cuchilla San Cayetano Integrated Management Regional Districts and the multiple protective forest reserves in the areas near Chingaza. In order to demonstrate whether PAs are ensuring habitat quality within the distribution of mammal species subject to use, we compared mean values of the HSFI of the distribution of the species in unprotected areas of the Cundinamarca Department and the mean value within all PAs. We found statistically significant differences ($T = 11.74$, $p < 0.01$) where almost all species have higher HSFI values throughout the Department than in PAs. On average, there is a difference of 10.72 points between the average HSFI of the Department and that of the PAs (Mean ± SD = 10.73 ± 5.98%). This shows that the state of the species' habitats is less impacted by human activities within PAs and that the conservation areas of most species depend, to a large extent, on them (Fig. 5).

Finally, when including the type of use and considering the differential pressure that different types of uses represent for each species, we found slight differences between representation and the level of human intervention on species ranges both in the whole Department and only inside PAs (Fig. 6). When comparing between species with and without use for each type, we only found significant differences for species subject to traffic/use as pets in terms of HSFI in the Department ($H = 3.95$, $p = 0.046$) and within PAs ($H = 5.93$, $p = 0.014$), with those species showing lower levels of intervention (Table 2). No significant differences were found for the rest of uses and for the three variables (Table 2). We found no differences between the types of uses for the three variables for those species subject to use (Table 2).

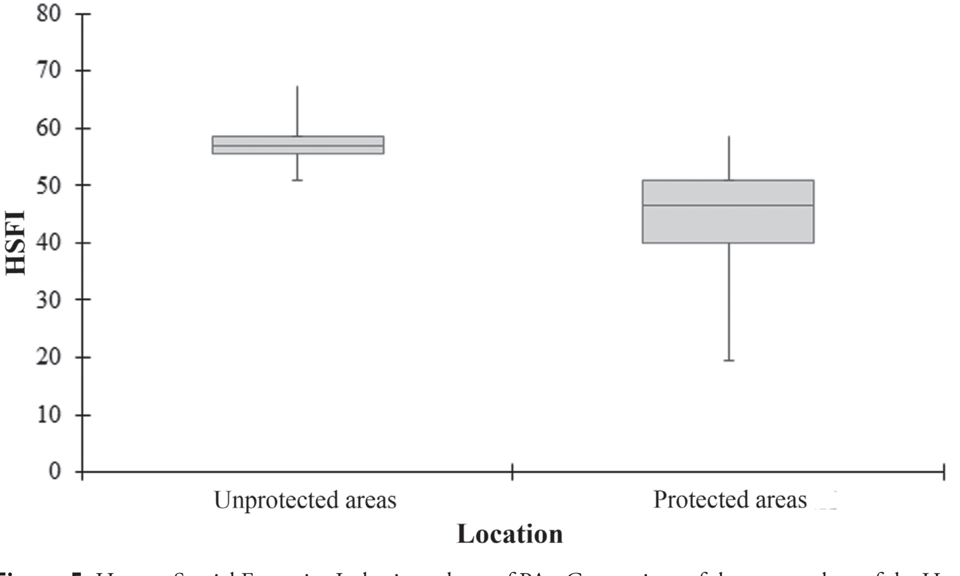

Figure 5. Human Spatial Footprint Index in and out of PAs. Comparison of the mean values of the Human Spatial Footprint Index of the distribution areas of the mammals subject to use inside and outside the PAs of the Department of Cundinamarca, Colombia.

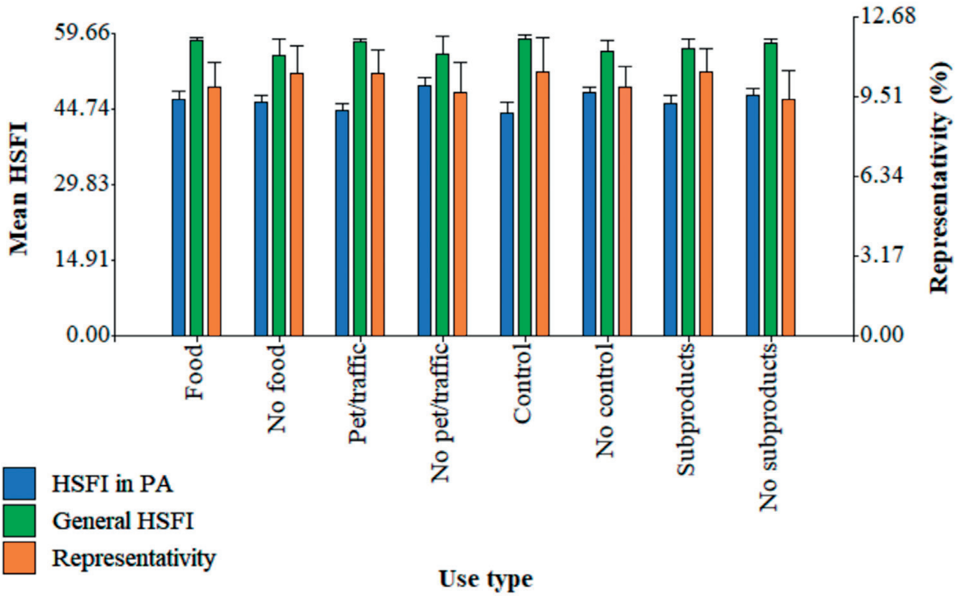

Figure 6. Human Spatial Footprint Index and representation for different species uses. Overall Human Spatial Footprint Index in the Department and within PAs compared with species subject to different types of uses in the Department of Cundinamarca, Colombia. Percentage of representation is on the secondary Y-axis.

Table 2. Comparison between mammal and use and no-use between different use types and for Human Spatial Footprint Index overall for the Department and within protected areas and for representation for the Department of Cundinamarca, Colombia. * Indicates significant differences.

Comparison	Type of use	Variable	H	p
Use / No use	Consumption	Representation	0.555	0.460
		HSFI Department	0.097	0.767
		HSFI in PA	0.059	0.824
	Control	Representation	0.099	0.765
		HSFI Department	1.733	0.188
		HSFI in PA	0.002	0.960
	Pet/traffic	Representation	0.200	0.654
		HSFI Department	3.959	0.040*
		HSFI in PA	5.936	0.014*
	Subproducts	Representation	0.656	0.421
		HSFI Department	0.002	0.9587
		HSFI in PA	0.153	0.697
Between uses	Consumption vs. Control vs. Pet/traffic vs. Subproducts	Representation	0.490	0.921
		HSFI in PA	1.753	0.624
		HSFI Department	1.073	0.783

Discussion

With its wide elevation gradient and mountainous topography, Cundinamarca harbours a wide variety of ecosystems and biodiversity (Conservación Internacional Colombia and Corporación Autónoma Regional de Cundinamarca 2011), even considered as part of one of the global hotspots: the Tropical Andes (Myers et al. 2000). However, the continuous historic and ongoing land-cover change (Etter and van Wyngaarden 2000; Etter et al. 2006; Correa Ayram et al. 2020), the high impact of human activities and the effects related to global change drivers have affected and will keep affecting biodiversity, in general, and mammals, in particular (Schipper et al. 2008; Correa Ayram et al. 2018; Castillo et al. 2020). Human influence across species ranges is usually conceived as one of the best proxies of species threats and risk, especially for species with a close relationship with humans or those directly affected by their use (Sanderson et al. 2002; Woolmer et al. 2008). Here, we presented one of the first systematic approaches to the effects of human influence on an ecological and culturally important group of species, as a basis for appropriate decision-making and for providing information for conservation.

Most of the species distribution and the correspondent richness values respond to the heterogeneity of the transition zone between the Andes and the lowlands of the inter-Andean valleys of the Magdalena River and the Llanos, both located in the same area of the transformation front and the area where the highest HSFI values are located (Correa Ayram et al. 2020). This is evident in the Department's eastern and western zones in the lower fringe of the mountain range, except for the areas within some PAs, like Chingaza PNN and the various protection figures that surround it (Fig. 3).

More than half of the species presented in the analysis have a representation value lower than 10%, with most of their ranges located outside PAs; therefore, depending to a large extent on actions and management that takes place in private lands, a situation that has been seen before in mammal species, such as jaguar and puma (de la Torre et al. 2017; Zárrate-Charry et al. 2018). Furthermore, no order showed representation values above 15%, which is lower than the global representation targets for elements, such as biomes related to the Aichi targets (Woodley et al. 2012; Bacon et al. 2019). These values are well below other required areas for some groups, such as carnivores, where more ambitious targets such as 30% representation are proposed to ensure their ecological needs (Di Minin et al. 2016). The species with the lowest representation for the Department of Cundinamarca are the southern tamandua (*Tamandua tetradactyla*), the black-capped capuchin (*Sapajus apella*) and the jaguar (*Panthera onca*). Reasons associated with such low representation are likely explained by the restricted distribution of these species in the Department (Alzate-Gaviria et al. 2016; Payán et al. 2016; Olaya-Rodríguez et al. 2020), mostly restricted to the lowland areas, where the distribution of PAs is scarce, as the Department's system of PAs is predominantly montane, located in areas > 2,000 m above sea level (RUNAP 2019). This is especially worrisome for species, such as the black-capped capuchin and the jaguar, since they depend on conserved landscapes or extensive areas with remnant natural habitats and, in both cases, their representation in PAs was below 5%. Remarkably, half of the nine threatened species showed representation values lower than 10%, which represents a significant threat to their survival, especially considering most of their threats are related to habitat loss and degradation which are very high in most of the Department, especially outside

PAs. Overall, the low representation within PAs for most species and the high level of transformation and human impact outside them, indicate the Department retains very unsuitable conditions for most species subject to use and, therefore, the probability of survival for the long term of most species in the Department is likely very low.

Natural cover remnants with good quality and with considerable size in the Department are scarce and poorly represented in PAs, as in most of the Andean Region (Armenteras et al. 2003) and the magnitude of human influence in the entire region is amongst the highest in the country, along with the Caribbean Region (Correa Ayram et al. 2020). Furthermore, given the generalised scarcity of information on the ecology of most species, including their habitat requirements, it is necessary to use other approaches to assess the current status or vulnerability of species through their habitats to increasing pressures related to anthropogenic variables (Collen et al. 2008; Leidig and Teeuw 2015). That is why we evaluated the influence of humans across the range of all mammal species subject to use by means of the Human Spatial Footprint Index (HSFI) and compared the status of species distribution in the Department and inside PAs, in order to evidence whether being inside a PA makes the magnitude of the impact of human pressures lower.

All species subject to use in the Department have a mean value of human influence over their entire distribution higher than 50, which is of particular concern since this value is well over the threshold of high intervention according to the Index (Correa Ayram et al. 2017; Correa Ayram et al. 2018). The two species that showed the mean higher values (> 60) were the long-tailed weasel (*Mustela frenata*) and the capybara (*Hydrochoerus hydrochaeris*). For the long-tailed weasel, for instance, the distribution includes a large part of the central zone of Cundinamarca, including Bogotá, the capital city of Colombia and its surrounding areas, some of the most populated and industrialised regions in the country (Gobernación de Cundinamarca 2020; González-Maya et al. 2021a). In general, the results indicate that human activities overall have fewer impacts over species' habitats within PAs and that the conservation areas for most species depend largely on them (Fig. 4). We found very few species with areas with low (< 30) index values, which means that, for the study area, there are no areas with a low human footprint (Fig. 5). This value is critical for supporting how to design conservation strategies since the existing PAs are not so extensive and have not been designed to ensure the representation of mammal species or, in fact, any other group; this translates in that conservation efforts depend mainly on private and productive areas, but in the Department, these are particularly adverse since they have very high values of human impact. Given that our focal species are already under severe pressure from their close relationship with humans, quality habitat then becomes an even more important aspect to be considered given the synergistic effect of multiple stressors over their populations. Our results should be considered when defining conservation actions or prioritisation processes for restoration or management zones in the Department to ensure at least the best remaining areas within an otherwise significantly transformed landscape.

Conclusions

Human activities have irreparably affected species habitats and the functioning of ecosystems globally, a dynamic that is becoming increasingly pronounced with catastrophic effects for biodiversity (Ceballos et al. 2015; González-Maya et al. 2017). This reality is no different for Cundinamarca, a Department that, like several in the Andean zone, has suffered the greatest impacts related to human activities in the country (Correa Ayram et al. 2018). Based on this reality, the needs and conservation planning for maintaining species is a great challenge, especially when managing species subject to use that possess characteristics that are part of the culture, use and tradition of human communities (Andrade Pérez and Corzo Mora 2011). Protected Areas have historically functioned as the cornerstone of conservation strategies (Stolton and Dudley 2010), being areas where species can exist and survive and, at the same time, function as a source for colonising recovered surrounding areas (Guerra et al. 2019). Currently, in Colombia, the role and importance of PAs are becoming increasingly evident, but the challenges for their maintenance are also increasing and it is urgent to ensure effective management of these areas and the landscapes that contain them (Ospina Moreno et al. 2020).

Our results make evident that the representation of mammal species within the existing PAs is below the globally defined thresholds and well below the requirements that most species may have (Di Minin et al. 2016; Wilson 2016). Likewise, the conservation status of habitats both inside and outside PAs is low and they have been subjected to various human impacts that make the HSFI values very high for the entire Department. Although the impact values associated with the HSFI are lower within PAs, they are not of optimal quality and efforts are required to redirect this trend and achieve landscape conservation and functionality. Currently, the development and planning of a new PA policy (CONPES 450) provide elements to improve the effectiveness and conservation of PAs and, at the same time, ensures that the surrounding landscapes are managed in a way that ensures the functionality of ecological processes and habitat and species connectivity. In the specific case of the mammals of Cundinamarca, this is critical because, to a large extent, their distribution areas and their management are located on private properties outside of conservation zones and only by strengthening management measures, land use plans and defining new conservation strategies can the maintenance of their habitats be warranted.

Acknowledgements

This work is part of the Project "Distribución histórica, actual y futura de mamíferos y sus relaciones e importancia sociocultural en el departamento de Cundinamarca: herramientas de planificación de conservación" funded by the Convocatoria 829-2018 Proyectos de I+D para el desarrollo tecnológico base biológica-Cundinamarca from the Ministerio de Ciencia, Tecnología e Innovación of Colombia, executed by Corporación Universitaria Minuto de Dios – UNIMINUTO and Proyecto de Conservación de Aguas y Tierras - ProCAT Colombia. We thank the supervisors at MINCIENCIAS and UNIMINUTO and to ProCAT Colombia staff for their support for the development of this project. Thanks to J. Schipper for improving the language. Additionally, we thank the editor and three anonymous reviewers for their comments that significantly improved the manuscript.

References

Alberti M, Marzluff JM (2004) Ecological resilience in urban ecosystems: Linking urban patterns to human and ecological functions. Urban Ecosystems 7(3): 241–265. https://doi.org/10.1023/B:UECO.0000044038.90173.c6

Alzate-Gaviria M, González-Maya JF, Botero-Botero A (2016) Distribución geográfica y estado de conocimiento de las especies del género *Tamandua* (Xenarthra: Myrmecophagidae) en Colombia. Edentata 17: 8–16. https://doi.org/10.2305/IUCN.CH.2016.Edentata-17-1.3.en

Andrade Pérez GI, Corzo Mora GA (2011) ¿Qué y dónde conservar? Parques Nacionales Naturales de Colombia. Unidad Administrativa Especial de Parques Nacionales Naturales de Colombia, Bogotá, Colombia, 197 pp.

Armenteras D, Gaast F, Villareal H (2003) Andean Forest fragmentation and the representativeness of protected natural areas in the eastern Andes, Colombia. Biological Conservation 113(2): 245–256. https://doi.org/10.1016/S0006-3207(02)00359-2

Armsworth PR, Chan KMA, Daily GC, Ehrlich PR, Kremen C, Ricketts TH, Sanjayan MA (2007) Ecosystem-service science and the way forward for conservation. Conservation Biology 21(6): 1383–1384. https://doi.org/10.1111/j.1523-1739.2007.00821.x

Aubry KB, Hayes JP, Biswell BL, Marcot BG (2003) The ecological role of three dwelling mammals in western coniferous forest. Management and conservation in the forest of western North America. Oregon State University, USA, 415–443. https://doi.org/10.1017/CBO9780511615757.013

Bacon E, Gannon P, Stephen S, Seyoum-Edjigu E, Schmidt M, Lang B, Sandwith T, Xin J, Arora S, Adham KN, Espinoza AJR, Qwathekana M, Prates APL, Shestakov A, Cooper D, Ervin J, Dias BFS, Leles B, Attallah M, Mulongoy J, Gidda SB (2019) Aichi Biodiversity Target 11 in the like-minded megadiverse countries. Journal for Nature Conservation 51: e125723. https://doi.org/10.1016/j.jnc.2019.125723

Barbosa Camargo SF (2020) Caracterización de las presiones de cacería y tráfico ilegal sobre mamíferos, aves y reptiles en la jurisdicción de la Corporación Autónoma Regional de Cundinamarca-CAR. Universidad Pedagógica y Tecnológica de Colombia, Tunja115 pp.

Beier P (1993) Determining minimum habitat areas and habitat corridors for cougars. Conservation Biology 7(1): 94–108. https://doi.org/10.1046/j.1523-1739.1993.07010094.x

Bogoni JA, Peres CA, Ferraz K (2020) Extent, intensity and drivers of mammal defaunation: A continental-scale analysis across the Neotropics. Scientific Reports 10(1): e14750. https://doi.org/10.1038/s41598-020-72010-w

Burneo SF, González-Maya JF, Tirira DG (2009) Distribution and habitat modelling for Colombian Weasel *Mustela felipei* in the Northern Andes. Small Carnivore Conservation 41: 41–45.

Castaño-Uribe C, González-Maya JF, Zárrate-Charry DA, Ange-Jaramillo C, Vela-Vargas IM (2013) Plan de Conservación de Felinos del Caribe colombiano: los felinos y su papel en la planificación regional integral basada en especies clave. Fundación Herencia Ambiental Caribe, ProCAT Colombia, The Sierra to Sea Institute, Santa Marta, Colombia, 232 pp.

Castillo LS, Correa Ayram CA, Matallana Tobón CL, Corzo G, Areiza A, González-M R, Serrano F, Chalán Briceño L, Sánchez Puertas F, More A, Franco O, Bloomfield H, Aguilera Orrury VL, Rivadeneira Canedo C, Morón-Zambrano V, Yerena E, Papadakis J, Cárdenas JJ, Golden Kroner RE, Godínez-Gómez O (2020) Connectivity of Protected Areas: effect of human pressure and subnational contributions in the ecoregions of tropical Andean countries. Land 9(8): e239. https://doi.org/10.3390/land9080239

Ceballos G, Ehrlich PR, Barnosky AD, Garcia A, Pringle RM, Palmer TM (2015) Accelerated modern human-induced species losses: entering the sixth mass extinction. Science Advances 1(5): e1400253. https://doi.org/10.1126/sciadv.1400253

Clerici N, Armenteras D, Kareiva P, Botero R, Ramirez-Delgado JP, Forero-Medina G, Ochoa J, Pedraza C, Schneider L, Lora C, Gomez C, Linares M, Hirashiki C, Biggs D (2020) Deforestation in Colombian protected areas increased during post-conflict periods. Scientific Reports 10(1): e4971. https://doi.org/10.1038/s41598-020-61861-y

Collen B, Ram M, Zamin T, McRae L (2008) The Tropical Biodiversity Data Gap: addressing disparity in global monitoring. Tropical Conservation Science 1(2): 75–88. https://doi.org/10.1177/194008290800100202

Conservación Internacional Colombia and Corporación Autónoma Regional de Cundinamarca (2011) Informe sobre el estado de la biodiversidad en la jurisdicción de la Corporación Autónoma Regional de Cundinamarca CAR. Conservación Internacional Colombia, Corporación Autónoma Regional de Cundinamarca, Bogotá, Colombia, 106 pp.

Correa Ayram CA, Mendoza ME, Etter A, Pérez Salicrup DR (2017) Anthropogenic impact on habitat connectivity: a multidimensional human footprint index evaluated in a highly biodiverse landscape of Mexico. Ecological Indicators 72: 895–909. https://doi.org/10.1016/j.ecolind.2016.09.007

Correa Ayram CA, Mendoza ME, Etter A, Pérez-Salicrup DR (2018) Effect of the landscape matrix condition for prioritizing multispecies connectivity conservation in a highly biodiverse landscape of Central Mexico. Regional Environmental Change 19(1): 149–163. https://doi.org/10.1007/s10113-018-1393-8

Correa Ayram CA, Etter A, Díaz-Timoté J, Rodríguez Buriticá S, Ramírez W, Corzo G (2020) Spatiotemporal evaluation of the human footprint in Colombia: Four decades of anthropic impact in highly biodiverse ecosystems. Ecological Indicators 117: e106630. https://doi.org/10.1016/j.ecolind.2020.106630

Cortés-Delgado N, Pérez-Torres J (2011) Habitat edge context and the distribution of phyllostomid bats in the Andean forest and anthropogenic matrix in the Central Andes of Colombia. Biodiversity and Conservation 20(5): 987–999. https://doi.org/10.1007/s10531-011-0008-1

Cortés-Gregorio I, Pascual-Ramos E, Medina-Torres SM, Sandoval-Forero EA, Lara-Ponce E, Piña-Ruíz HH, Martínez-Ruíz R, Rojo-Martínez GE (2013) Etnozoología del pueblo Mayo-Yoreme en el norte de Sinaloa: uso de vertebrados silvestres. Revista de Agricultura. Sociedad y Desarrollo 10: 335–358.

Cullen L, Sana DA, Lima F, deAbreu KC, Uezu A (2013) Selection of habitat by the jaguar, *Panthera onca* (Carnivora: Felidae), in the upper Paraná River, Brazil. Zoologia 30: 379–387. https://doi.org/10.1590/S1984-46702013000400003

Cunha-Ribeiro G, Schiavetty A (2009) Conocimiento, creencias y utilización de la mastofauna por los pobladores del Parque Estatal de la Sierra de Conduru, Bahía, Brasil. In: Costa-Neto EM, Santos-Fita D, Vargas-Clavijo M (Eds) Manual de etnozoología: una guía teórico-práctica para investigar la interconexión del ser humano con los animales. Tundra Ediciones, Valencia, 224–241.

Curtis PG, Slay CM, Harris NL, Tyukavina A, Hansen MC (2018) Classifying drivers of global forest loss. Science 361(6407): 1108–1111. https://doi.org/10.1126/science.aau3445

DANE (2019) Población censal ajustada por cobertura y porcentajes de omisión nacional y departamental por área. https://www.dane.gov.co

Davey AG (1998) National System Planning for Protected Areas. International Union for the Conservation of Nature and Natural Resources, Gland, 71 pp. https://doi.org/10.2305/IUCN.CH.1998.PAG.1.en

de la Torre JA, Núñez JM, Medellín RA (2017) Spatial requirements of jaguars and pumas in Southern Mexico. Mammalian Biology Zeitschrift fur Saugetierkunde 84: 52–60. https://doi.org/10.1016/j.mambio.2017.01.006

Di Minin E, Slotow R, Hunter LT, Montesino Pouzols F, Toivonen T, Verburg PH, Leader-Williams N, Petracca L, Moilanen A (2016) Global priorities for national carnivore conservation under land use change. Scientific Reports 6(1): e23814. https://doi.org/10.1038/srep23814

Environmental Systems Research Institute (2016) ArcGIS 10.5. Environmental Systems Research Institute, Redlands, California.

Etter A, van Wyngaarden W (2000) Patterns of landscape transformation in Colombia, with emphasis in the Andean region. Ambio 29(7): 432–439. https://doi.org/10.1579/0044-7447-29.7.432

Etter A, McAlpine C, Wilson K, Phinn S, Possingham H (2006) Regional patterns of agricultural land use and deforestation in Colombia. Agriculture, Ecosystems & Environment 114(2–4): 369–386. https://doi.org/10.1016/j.agee.2005.11.013

Etter A, McAlpine C, Possingham H (2008) Historical Patterns and Drivers of Landscape Change in Colombia Since 1500: A Regionalized Spatial Approach. Annals of the Association of American Geographers 98(1): 2–23. https://doi.org/10.1080/00045600701733911

Ferraro PJ, Hanauer MM, Sims KR (2011) Conditions associated with protected area success in conservation and poverty reduction. Proceedings of the National Academy of Sciences of the United States of America 108(34): 13913–13918. https://doi.org/10.1073/pnas.1011529108

Fick SE, Hijmans RJ (2017) WorldClim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37(12): 4302–4315. https://doi.org/10.1002/joc.5086

Fischer C, Muchapondwa E, Sterner T (2010) A Bio-Economic Model of Community Incentives for Wildlife Management Under CAMPFIRE. Environmental and Resource Economics 48(2): 303–319. https://doi.org/10.1007/s10640-010-9409-y

Forero-Medina G, Joppa L (2010) Representation of global and national conservation priorities by Colombia's Protected Area Network. PLoS ONE 5(10): e13210. https://doi.org/10.1371/journal.pone.0013210

Gannon P, Dubois G, Dudley N, Ervin J, Ferrier S, Gidda S, MacKinnon K, Richardson K, Schmidt M, Seyoum-Edjigu E, Shestakov A (2019) An update on progress towards Aichi Biodiversity Target 11. Parks 25(25.2): 7–18. https://doi.org/10.2305/IUCN.CH.2019.PARKS-25-2PG.en

González-Maya JF, Víquez-R LR, Belant JL, Ceballos G (2015) Effectiveness of Protected Areas for representing species and populations of terrestrial mammals in Costa Rica. PLoS ONE 10(5): e0124480. https://doi.org/10.1371/journal.pone.0124480

González-Maya JF, Víquez-R LR, Arias-Alzate A, Belant JL, Ceballos G (2016) Spatial patterns of species richness and functional diversity in Costa Rican terrestrial mammals: Implications for conservation. Diversity & Distributions 22(1): 43–56. https://doi.org/10.1111/ddi.12373

González-Maya JF, Martinez-Meyer E, Medellin R, Ceballos G (2017) Distribution of mammal functional diversity in the Neotropical realm: Influence of land-use and extinction risk. PLoS ONE 12(4): e0175931. https://doi.org/10.1371/journal.pone.0175931

González-Maya JF, Rodríguez-Álvarez C, Arias-Bernal L (2021a) Registros de mamíferos medianos y grandes en la Reserva Natural de la Sociedad Civil Jaime Duque, Cundinamarca, Colombia. Revista Mexicana de Mastozoología 11(1): 64–69. https://doi.org/10.22201/ie.20074484e.2021.11.1.328 [Nueva Epoca]

González-Maya JF, Lemus-Mejía L, Gómez-Junco GP, Aguirre-Sierra L, Moreno-Díaz C, Vélez-García F, Morales-Perdomo JA (2021b) Distribución histórica, actual y futura de mamíferos y sus relaciones e importancia sociocultural en el departamento de Cundinamarca: herramientas de planificación de conservación. Informe técnico final Programas y proyectos de CTel Convocatoria 829-2018 Proyectos de I+D para el desarrollo tecnológico base biológica-Cundinamarca. Corporación Universitaria Minuto de Dios - UNIMINUTO, Proyecto de Conservación de Aguas y Tierras - ProCAT Colombia, Ministerio de Ciencia, Tecnología e Innovación, Bogotá, Colombia, 230 pp.

Green EJ, McRae L, Freeman R, Harfoot MBJ, Hill SLL, Baldwin-Cantello W, Simonson WD (2020) Below the canopy: Global trends in forest vertebrate populations and their drivers. Proceedings. Biological Sciences 287(1928): e20200533. https://doi.org/10.1098/rspb.2020.0533

Gobernación de Cundinamarca (2020) Plan de desarrollo departamental, 2020–2024. http://www.cundinamarca.gov.co/Home/SecretariasEntidades.gc/Secretariadeplaneacion/SecretariadeplaneacionDespliegue/aspoliyplanprog_contenidos/csecreplanea__plandesarrdep_2020_2023

Guerra CA, Rosa IMD, Pereira HM (2019) Change versus stability: Are protected areas particularly pressured by global land cover change? Landscape Ecology 34(12): 2779–2790. https://doi.org/10.1007/s10980-019-00918-4

Harfoot MBJ, Johnston A, Balmford A, Burgess ND, Butchart SHM, Dias MP, Hazin C, Hilton-Taylor C, Hoffmann M, Isaac NJB, Iversen LL, Outhwaite CL, Visconti P, Geldmann J (2021) Using the IUCN Red List to map threats to terrestrial vertebrates at global scale. Nature Ecology & Evolution 5: 1510–1519. https://doi.org/10.1038/s41559-021-01542-9

House C, Redmond D, Phillips MR (2017) An assessment of the efficiency and ecological representativity of existing marine reserve networks in Wales, UK. Ocean and Coastal Management 149: 217–230. https://doi.org/10.1016/j.ocecoaman.2017.04.016

IDEAM, IGAC, IAvH, INVEMAR, SINCHI, IIAP (2017) Ecosistemas continentales, costeros y marinos de Colombia. Instituto de Hidrología, Meteorología y Estudios Ambientales, Instituto Geográfico Agustín Codazzi, Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Instituto de Investigaciones Marinas y Costeras "José Benito Vives de Andréis, Instituto Amazónico de Investigaciones Científicas SINCHI, Instituto de Investigaciones Ambientales del Pacífico Jhon von Neumann, Bogotá, Colombia.

Instituto Geográfico Agustín Codazzi (2016) Cartografía básica digital integrada. Republica de Colombia. Escala 1:100.000. IGAC, Bogotá, Colombia.

IUCN (2018) IUCN Red List of Threatened Species. www.iucnredlist.org [accessed November 2.2018]

Kass JM, Vilela B, Aiello-Lammens ME, Muscarella R, Merow C, Anderson RP, O'Hara RB (2018) Wallace: A flexible platform for reproducible modeling of species niches and distributions built for community expansion. Methods in Ecology and Evolution 9(4): 1151–1156. https://doi.org/10.1111/2041-210X.12945

Lacher Jr TE, Davidson AD, Fleming TH, Gómez-Ruiz EP, McCracken GF, Owen-Smith N, Peres CA, Vander Wall SB (2019) The functional roles of mammals in ecosystems. Journal of Mammalogy 100(3): 942–964. https://doi.org/10.1093/jmammal/gyy183

Leidig M, Teeuw RM (2015) Quantifying and Mapping Global Data Poverty. PLoS ONE 10(11): e0142076. https://doi.org/10.1371/journal.pone.0142076

Lemus-Mejía L (2021) Diversidad funcional como herramienta para la planificación territorial ante escenarios de cambio climático: estudio de caso con mamíferos en Cundinamarca, Colombia. MSc Thesis, Pontificia Universidad Javeriana, Bogotá.

Loucks C, Ricketts TH, Naidoo R, Lamoreux J, Hoekstra J (2008) Explaining the global pattern of protected area coverage: Relative importance of vertebrate biodiversity, human activities and agricultural suitability. Journal of Biogeography 35(8): 1337–1348. https://doi.org/10.1111/j.1365-2699.2008.01899.x

Luck GW, Harrington R, Harrison PA, Kremen C, Berry PM, Bugter R, Dawson TP, de Bello F, Díaz S, Feld CK, Haslett JR, Hering D, Kontogianni A, Lavorel S, Rounsevell M, Samways MJ, Sandin L, Settele J, Sykes MT, van den Hove S, Vandewalle M, Zobel M (2009) Quantifying the contribution of organisms to the provision of ecosystem services. Bioscience 59(3): 223–235. https://doi.org/10.1525/bio.2009.59.3.7

Magioli M, Rios E, Benchimol M, Casanova DC, Ferreira AS, Rocha J, Melo FR, Dias MP, Narezi G, Crepaldi MO, Mendes LÂM, Nobre RA, Chiarello AG, García-Olaechea A, Nobre AB, Devids CC, Cassano CR, Koike CDV, São Bernardo CS, Homem DH, Ferraz DS, Abreu DL, Cazetta E, Lima EF, Bonfim FCG, Lima F, Prado HA, Santos HG, Nodari JZ, Giovanelli JGR, Nery MS, Faria MB, Ferreira PCR, Gomes PS, Rodarte R, Borges R, Zuccolotto TFS, Sarcinelli TS, Endo W, Matsuda Y, Camargos VL, Morato RG (2021) The role of protected and unprotected forest remnants for mammal conservation in a megadiverse Neotropical hotspot. Biological Conservation 259: e109173. https://doi.org/10.1016/j.biocon.2021.109173

Ministerio de Ambiente y Desarrollo Sostenible, Fundación Omacha (2016) Plan de manejo para la conservación de las nutrias (*Lontra longicaudis* y *Pteronura brasiliensis*) en Colombia. Ministerio de Ambiente y Desarrollo Sostenible, Bogotá, 104 pp.

Ministerio del Ambiente, Wildlife Conservation Society (2014) Plan de Acción para la conservación del Jaguar en el Ecuador. Ministerio del Ambiente, Wildlife Conservation Society, Liz Claiborne & Art Ortenberg Foundation, Wild4Ever, Quito, 37 pp.

Murillo-Sandoval PJ, Gjerdseth E, Correa-Ayram C, Wrathall D, Van Den Hoek J, Dávalos LM, Kennedy R (2021) No peace for the forest: rapid, widespread land changes in the Andes-Amazon region following the Colombian civil war. Global Environmental Change 69: e102283. https://doi.org/10.1016/j.gloenvcha.2021.102283

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GA, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403(6772): 853–858. https://doi.org/10.1038/35002501

Nickel BA, Suraci JP, Allen ML, Wilmers CC (2020) Human presence and human footprint have non-equivalent effects on wildlife spatiotemporal habitat use. Biological Conservation 241: e108383. https://doi.org/10.1016/j.biocon.2019.108383

Nori J, Lemes P, Urbina-Cardona N, Baldo D, Lescano J, Loyola R (2015) Amphibian conservation, land-use changes and protected areas: a global overview. Biological Conservation 191: 367–374. https://doi.org/10.1016/j.biocon.2015.07.028

Noss AJ, Gardner B, Maffei L, Cuéllar E, Montaño R, Romero-Muñoz A, Sollman R, O'Connell AF, Altwegg R (2012) Comparison of density estimation methods for mammal populations with camera traps in the Kaa-Iya del Gran Chaco landscape. Animal Conservation 15(5): 527–535. https://doi.org/10.1111/j.1469-1795.2012.00545.x

Olaya-Rodríguez MH, Noguera-Urbano E, Gutiérrez C (2020) Atlas de la biodiversidad de Colombia. Primates. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá D.C., 51 pp.

Olmos-Martínez E, González-Ávila ME, Contreras-Loera MR (2013) Percepción de la población frente al cambio climático en áreas naturales protegidas de Baja California Sur, México. Polis 35: 1–21. https://doi.org/10.4067/S0718-65682013000200020

Osbahr K, Morales N (2012) Conocimiento local y usos de la fauna silvestre en el municipio de San Antonio del Tequendama (Cundinamarca, Colombia). Revista Udca Actualidad & Divulgacion Cientifica 15(1): 187–197. https://doi.org/10.31910/rudca.v15.n1.2012.816

Ospina Moreno M, Chamorro Ruiz S, Anaya García C, Echeverri Ramírez P, Atuesta C, Zambrano H, Abud M, Herrera CM, Ciontescu N, Guevara O, Zarrate D, Barrero A (2020) Guía para la planificación del manejo en las áreas protegidas del SINAP Colombia. Ministerio de Ambiente y Desarrollo Sostenible, Bogotá, 81 pp.

Parques Nacionales Naturales de Colombia (2021) Estandarización de presiones antrópicas en las áreas protegidas administradas por Parques Nacionales Naturales de Colombia. Parques Nacionales Naturales de Colombia, Bogotá, 39 pp.

Payán E, Soto C, Ruíz-García M, Nijhawan S, González-Maya JF, Valderrama C, Castaño-Uribe C (2016) Unidades de conservación, conectividad y calidad de hábitat del jaguar en Colombia. In: Medellín R, Chávez C, de la Torre A, Zarza H, Ceballos G (Eds) El Jaguar en el Siglo XXI: La perspectiva continental. Fondo de Cultura Económica, México city, 240–274.

Peterson AT, Soberón J, Pearson RG, Anderson RP, Martínez-Meyer E, Nakamura M, Bastos Araújo M (2011) Ecological niches and geographic distributions. Princeton University Press, Princeton, New Jersey, 328 pp. https://doi.org/10.23943/princeton/9780691136868.003.0003

Pineda-Guerrero A, González-Maya JF, Pérez-Torres J (2015) Conservation value of forest fragments for medium-sized carnivores in a silvopastoral system in Colombia. Mammalia 79: 115–119. https://doi.org/10.1515/mammalia-2013-0050

Prugh LR, Stoner CJ, Epps CW, Bean WT, Ripple WJ, Laliberte AS, Brashares JS (2009) The Rise of the Mesopredator. Bioscience 59(9): 779–791. https://doi.org/10.1525/bio.2009.59.9.9

R Team Development Core (2021) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna.

Racero-Casarrubia JA, Vidal CC, Ruíz OD, Ballesteros J (2008) Percepción y patrones de uso de la fauna silvestre por las comunidades indígenas Embera-Katíos en la cuenca del río San Jorge, zona amortiguadora del PNN-Paramillo. Revista de Estudios Sociales 31(31): 118–131. https://doi.org/10.7440/res31.2008.08

Ramírez-Chaves HE, Suárez-Castro AF Sociedad Colombiana de Mastozoología, Zurc D, Concha Osbahr DC, Trujillo A, Noguera-Urbano EA, Pantoja-Peña GE, Rodríguez-Posada ME, González-Maya JF, Pérez-Torres J, Mantilla-Meluk H, López-Castañeda C, Velásquez-Valencia A, Zárrate-Charry D (2019) Mamíferos de Colombia. Version 1.6. In: Mastozoología SCd (Ed.) Checklist dataset. 1.6 ed. GBIF.org, Bogotá.

Ripple WJ, Estes JA, Beschta RL, Wilmers CC, Ritchie EG, Hebblewhite M, Berger J, Elmhagen B, Letnic M, Nelson MP, Schmitz OJ, Smith DW, Wallach AD, Wirsing AJ (2014) Status and ecological effects of the world's largest carnivores. Science 343(6167): e1241484. https://doi.org/10.1126/science.1241484

Roncancio-Duque NJ, Vélez Vanegas LA (2019) Valores objeto de conservación del subsistema de áreas protegidas de los Andes occidentales, Colombia. Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales 43(166): e52. https://doi.org/10.18257/raccefyn.719

Rondinini C, Boitani L, Rodrigues AS, Brooks TM, Pressey RL, Visconti P, Baillie JE, Baisero D, Cabeza M, Crooks KR, Di Marco M, Redford KH, Andelman SA, Hoffmann M, Maiorano L, Stuart SN, Wilson KA (2011) Reconciling global mammal prioritization schemes into a strategy. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 366(1578): 2722–2728. https://doi.org/10.1098/rstb.2011.0112

RUNAP (2019) Registro Único Nacional de Áreas Protegidas – RUNAP. Áreas Protegidas asociadas al departamento de Cundinamarca. RUNAP, Bogotá.

Sánchez F, Sánchez-Palomino P, Cadena A (2004) Inventario de mamíferos en un bosque de los Andes centrales de Colombia. Caldasia 26: 291–309.

Sánchez-Azofeifa GA, Quesada-Mateo C, González-Quesada P, Dayanandan S, Bawa KS (1999) Protected areas and conservation of biodiversity in the Tropics. Conservation Biology 13(2): 407–411. https://doi.org/10.1046/j.1523-1739.1999.013002407.x

Sanderson EW, Jaiteh M, Levy MA, Redford KH, Wannebo AV, Woolmer G, Woolmer G (2002) The human footprint and the last of the wild. Bioscience 52(10): 891–904. https://doi.org/10.1641/0006-3568(2002)052[0891:THFATL]2.0.CO;2

Schipper J, Chanson JS, Chiozza F, Cox NA, Hoffmann M, Katariya V, Lamoreux J, Rodrigues AS, Stuart SN, Temple HJ, Baillie J, Boitani L, Lacher Jr TE, Mittermeier RA, Smith AT, Absolon D, Aguiar JM, Amori G, Bakkour N, Baldi R, Berridge RJ, Bielby J, Black PA, Blanc JJ, Brooks TM, Burton JA, Butynski TM, Catullo G, Chapman R, Cokeliss Z, Collen B, Conroy J, Cooke JG, da Fonseca GA, Derocher AE, Dublin HT, Duckworth JW, Emmons L, Emslie RH, Festa-Bianchet M, Foster M, Foster S, Garshelis DL, Gates C, Gimenez-Dixon M, Gonzalez S, González-Maya JF, Good TC, Hammerson G, Hammond PS, Happold D, Happold M, Hare J, Harris RB, Hawkins CE, Haywood M, Heaney LR, Hedges S, Helgen KM, Hilton-Taylor C, Hussain SA, Ishii N, Jefferson TA, Jenkins RK, Johnston CH, Keith M, Kingdon J, Knox DH, Kovacs KM, Langhammer P, Leus K, Lewison R, Lichtenstein G, Lowry LF, Macavoy Z, Mace GM, Mallon DP, Masi M, McKnight MW, Medellin RA, Medici P, Mills G, Moehlman PD, Molur S, Mora A, Nowell K, Oates JF, Olech W, Oliver WR, Oprea M, Patterson BD, Perrin WF, Polidoro BA, Pollock C, Powel A, Protas Y, Racey P, Ragle J, Ramani P, Rathbun G, Reeves RR, Reilly SB, Reynolds 3rd JE, Rondinini C, Rosell-Ambal RG, Rulli M, Rylands AB, Savini S, Schank CJ, Sechrest W, Self-Sullivan C, Shoemaker A, Sillero-Zubiri C, De Silva N, Smith DE, Srinivasulu C, Stephenson PJ, van Strien N, Talukdar BK, Taylor BL, Timmins R, Tirira DG, Tognelli MF, Tsytsulina K, Veiga LM, Vie JC, Williamson EA, Wyatt SA, Xie Y, Young BE (2008) The status of the world's land and marine mammals: Diversity, threat, and knowledge. Science 322: 225–230. https://doi.org/10.1126/science.1165115

Sims KRE, Alix-Garcia JM (2017) Parks versus PES: Evaluating direct and incentive-based land conservation in Mexico. Journal of Environmental Economics and Management 86: 8–28. https://doi.org/10.1016/j.jeem.2016.11.010

Sinclair ARE (2003) Mammal population regulation, keystone processes and ecosystem dynamics. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 358(1438): 1729–1740. https://doi.org/10.1098/rstb.2003.1359

Stolton S, Dudley N (2010) Arguments for Protected Areas: multiple benefits for conservation and use. Earthscan, New York, 296 pp. https://doi.org/10.4324/9781849774888

Tinoco-Sotomayor AN, Zarrate-Charry D, Navas-S GR, González-Maya JF (2021) Valores de uso y amenazas sobre los mamíferos medianos y grandes del Distrito de Cartagena de Indias, Colombia. Caldasia 43(2): 379–391. https://doi.org/10.15446/caldasia.v43n2.84872

Van Vliet N, Gomez J, Quiceno-Mesa MP, Escobar JF, Andrade G, Vanegas LA, Nasi R (2015) Sustainable wildlife management and legal commercial use of bushmeat in Colombia: The resource remains at the cross-road. International Forestry Review 17(4): 438–447. https://doi.org/10.1505/146554815817476521

Vargas-Clavijo M (2008) Apropiación de la fauna como patrimonio zoocultural. Boletín Patrimonio Hoy 2: 1–4.

Vargas-Clavijo M (2009) Patrimonio zoocultural: el mundo animal en las expresiones tradicionales de los pueblos. In: Costa-Neto EM, Santos Fita D, Vargas-Clavijo M (Eds) Manual de etno-zoología Una guía teórico-práctica para investigar la interconexión del ser humano con los animales. Tundra Ediciones, Valencia, España, 118–141.

Venter O, Sanderson EW, Magrach A, Allan JR, Beher J, Jones KR, Possingham HP, Laurance WF, Wood P, Fekete BM, Levy MA, Watson JE (2016) Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. Nature Communications 7(1): e12558. https://doi.org/10.1038/ncomms12558

Wilson EO (2016) Half-Earth: our planet's fight for life. Liveright, New York, 272 pp.

Woodley S, Bertzky B, Crawhall N, Dudley N, Londoño JM, MacKinnon K, Redford KH, Sandwith T (2012) Meeting Aichi Target 11: What does success look like for protected area systems. Parks 18: 23–36.

Woolmer G, Trombulak SC, Ray JC, Doran PJ, Anderson MG, Baldwin RF, Morgan A, Sanderson EW (2008) Rescaling the human footprint: A tool for conservation planning at an ecoregional scale. Landscape and Urban Planning 87(1): 42–53. https://doi.org/10.1016/j.landurbplan.2008.04.005

Zárrate-Charry D (2018) Use of species distribution information to support landscape management in data-poor countries. PhD, Oregon State University, Corvallos, OR.

Zárrate-Charry DA, Massey AL, González-Maya JF, Betts MG (2018) Multi-criteria spatial identification of carnivore conservation areas under data scarcity and conflict: A jaguar case study in Sierra Nevada de Santa Marta, Colombia. Biodiversity and Conservation 27(13): 3373–3392. https://doi.org/10.1007/s10531-018-1605-z

Zárrate Charry DA, González-Maya JF, Arias-Alzate A, Jiménez-Alvarado JS, Reyes Arias JD, Armenteras D, Betts MG (2022) Connectivity conservation at the crossroads: protected areas versus payments for ecosystem services in conserving connectivity for Colombian carnivores. Royal Society Open Science 9: e201154. https://doi.org/10.1098/rsos.201154