Papéis Avulsos de Zoologia
Museu de Zoologia da Universidade de São Paulo

ARTICLE

Andean bear *(Tremarctos ornatus)* population density and relative abundance at the buffer zone of the Chingaza National Natural Park, cordillera oriental of the colombian andes

Daniel Rodríguez[1,5]; Adriana Reyes[1,6]; Andres Quiñones-Guerrero[1,7]; Fidel Ernesto Poveda-Gómez[2,8]; Yeimy Castillo-Navarro[1,9]; Robinson Duque[3,10] & Nicolás Rafael Reyes-Amaya[1,4,11]

[1] Fundación para la Investigación, Protección y Conservación del Oso Andino (Fundación Wii). Bogotá, Colombia.
[2] Corporación Manaba (Manaba). Bogotá, Colombia.
[3] Empresa de Acueducto y Alcantarillado de Bogotá (EAAB). Bogotá, Colombia.
[4] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Unidad Ejecutora Lillo (CONICET-UEL). San Miguel de Tucumán, Tucumán, Argentina.
[5] ORCID: http://orcid.org/0000-0002-4959-0561. E-mail: danielosito85@hotmail.com
[6] ORCID: http://orcid.org/0000-0002-7205-0950. E-mail: shisdre@hotmail.com
[7] ORCID: http://orcid.org/0000-0002-2882-4365. E-mail: andres2090005@gmail.com
[8] ORCID: http://orcid.org/0000-0003-4459-5010. E-mail: fepovedag@unal.edu.co
[9] ORCID: http://orcid.org/0000-0003-2263-0313. E-mail: yeimy.uis@gmail.com
[10] ORCID: http://orcid.org/0000-0001-7481-3715. E-mail: robinsonduque08@gmail.com
[11] ORCID: http://orcid.org/0000-0001-8509-3741. E-mail: nrreyesa@unal.edu.co (corresponding author)

Abstract. The Andean bear *(Tremarctos ornatus)* population density and relative abundance within the Chingaza Massif were assessed between September 2015 and May 2016. One hundred seventeen (117) camera traps were installed at 9 grids: 13 cameras per grid, each camera separated 750 m from the other; the sampling effort was 17,057 days-trap. Two thousand seven hundred eighty-four (2,784) native fauna records were obtained, 1,456 corresponding to mammals, 183 records for Andean bear specimens, 158 of them independent bear records (at least one hour between records), and 106 effective-independent bear records (also permitting individual recognition). Fifty-seven (57) Andean bear individuals were identified according to key external morphological features. Sixteen (16) adults were recaptured (12 males and 4 females), with a maximum mean distance of 27.22 km. Bears population density was 2.9 bears per 100 km^2. Based on this density and the buffer area of the sampling grids, we estimated an overall number of 122 bears in 4,215.15 km^2. The estimated density is the first for the species in Colombia and the lowest regarding previous reports from other countries. Thus, it is necessary to better understand how integral habitat quality and the anthropic impacts on habitat quality, availability, and connectivity may affect the Andean bear population densities in Colombia, as a useful tool for assessing populations` state and focus future conservation actions.

Key-Words. Andean bear; Conservation; Camera trapping; Population density; Relative abundance.

INTRODUCTION

Population assessments have been usually made to know the conservation status of different wildlife species (Van Horne, 1983; Witmer Gary, 2005), as biological information on populations state constitute a key tool allowing design and execution of accurate mid and long-term conservation actions (Rodríguez *et al.,* 2019a). Previous Andean bear *(Tremarctos ornatus)* population assessments have extrapolated data from black bear *Ursus americanus* (Peyton, 1999), related it to available habitat areas (Kattan *et al.,* 2004), used camera-trapping to distinguish individuals (Ríos-Uzeda *et al.,* 2007; Zug, 2009; Van Horn *et al.,* 2014, 2015; Reyes *et al.,* 2017) and estimated population densities; Ríos-Uzeda *et al.* (2007) estimated a density of 4.4-6 bears/100 km^2 in Bolivia, Molina *et al.* (2017) and Morrell (2014) estimated 7.45 and 3.9 bears/100 km^2 (respectively) in Ecuador, whereas Viteri (2007) estimated between 3 and 7 bears/100 km^2 also in Ecuador based on genetic studies, pointing possible differences from trapping responses. Population estimations based on camera-trapping should consider several uncertainties derived from population openness, sam-

Pap. Avulsos Zool., 2020; v.60: e20206030
http://doi.org/10.11606/1807-0205/2020.60.30
http://www.revistas.usp.br/paz
http://www.scielo.br/paz
Edited by: Luís Fábio Silveira
Received: 18/07/2019
Accepted: 29/05/2020
Published: 16/07/2020

ISSN On-Line: 1807-0205
ISSN Printed: 0031-1049
ISNI: 0000-0004-0384-1825

ple size, probability of capture, location and spatial distribution of the cameras, and size of the study and effective trapping areas (Foster & Harmsen, 2011; Garshelis, 2011), along with detectability and individuals identification (Zug, 2009; Jones, 2010; Reyes *et al.,* 2017). Thus, the relative abundance and population density of Andean bears at the buffer zone of the Chingaza National Natural Park within the Chingaza Massif (Cordillera oriental of the Colombian Andes), was estimated, as a useful tool for assessing populations` state and focus future conservation actions.

MATERIAL AND METHODS

Study area

The study area is located between 2,241 and 3,980 m elevation in the Macizo de Chingaza (Chingaza Massif), on the Cordillera Oriental (Eastern Ringe) of the Colombian Andes, both in Cundinamarca and Meta Departments (Fig. 1). The higher areas have variable topography and steep relief, including major escarpments (PNN, 2016). This altitudinal gradient includes, from lower to upper, Andean forest, High Andean forest, sub-páramo and páramo (PNN, 2005). The slightly disturbed or undisturbed natural forests correspond to humid Andean forest, with canopies up to 20 m high. The páramo is characterized by open vegetation

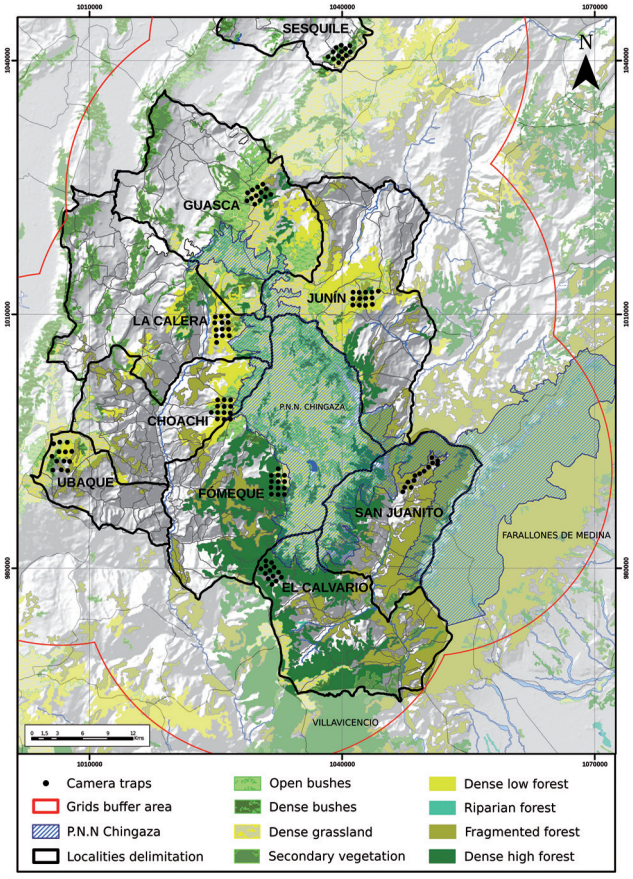

Figure 1. Natural covers map showing camera traps distribution at 9 grids throughout the study area.

dominated by *frailejonal* (Espeletiinae shrubs), *pajonal* (*Calamagrostis effusa* grasslands), *chuscal* (*Chusquea tesellata* reeds) and *turberas* (peat bog wetlands) (IDEAM *et al.,* 2007), the latter originated by small glacial cavities at the highest altitudes (Sguerra *et al.,* 2011). A monomodal rain regime occurs in this massif, influenced by the trade winds coming from the east, with a peak between May and August and the lowest precipitations between December and February (IDEAM, 2013). A natural covers map of the study area is provided (Fig. 1), with 30-meters resolution, based on Landsat, Rapid Eye, and Spot satellite images from the period 2010-2012, extracted from the Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia (IDEAM, 2014). Additionally, the principal landscape covers obtained from (IDEAM, 2014) are provided for each locality of the study area (with the percentage area of each category at a certain locality, regarding the total area of that category for the whole localities): Natural forest (including Dense high forest, Dense low forest, Fragmented forest, Riparian forest, Secondary/transitional vegetation, and Dense bushes), Páramo (Open bushes, and Dense grassland), Pastures (Clean pastures, Weedy pastures, and Mosaic of pastures and crops) and Croplands (Mosaic of crops, pastures and natural spaces, Mosaic of crops and natural spaces, Mosaic of crops, Confined crops, and Tubers) (Table 1).

Camera-trapping

One hundred seventeen Trophy Cam HD and Aggressor Bushnell camera traps programmed in video mode (Reyes *et al.,* 2017) were installed at single camera trap stations separated by 750 m, forming 9 grids through the study area (13 cameras per grid), with 3.7 km^2 extent each grid and separated by ≈ 17.1 km (Chávez *et al.,* 2013) (Fig. 1). The distance between cameras within the grids corresponds to ≈ 10% of the lowest female home range reported for the species (Castellanos, 2011). The grids were established in forest places with many signs of bear presence, at 7 municipalities in the Department of Cundimarca (Sequilé, Ubaque, Fómeque, Guasca, La Calera, Choachí, and Junín) and 2 municipalities in the Department of Meta (San Juanito and El Calvario, Fig. 1). Cameras in San Juanito (Meta) were arranged along a natural bear trail in the forest (not in a grid), because of minefields deployed at the zone by the armed conflict experienced in Colombia (Fig. 1).

The cameras operated during 9 months between September 2015 and May 2016, across a humid-dry and a dry-humid transitional seasons (Jaramillo-Robledo & Chaves-Cordoba, 2000), 24 hours a day. Cameras recorded 60 seconds videos for every record event of the camera, with a 1-second rest interval. Every bear record (or other fauna) included different amount of videos, depending on the time the individual spent at the camera visual range. Bear records were considered as independent from others just if they were recorded with at least 1-hour difference or in a different camera. Bear records

Table 1. Number of mammal and bear records, identified and recaptured bears, relative bears abundance, and landscape covers at the study area. Landscape covers for each locality represent the percentage area of each category at a certain locality, regarding the total area of that category for the whole localities.

Grid locality	Mammal records	Bear records	Independent bear records	Effective-independent bear records	Individuals identified	Individuals recaptured	Relative bears abundance	Natural forest (% of the total category area)	Páramo (% of the total category area)	Pastures (% of the total category area)	Croplands (% of the total category area)
Choachí	117	46	42	25	11	5	35.90	5.84	4.87	6.72	23.96
Junín	224	91	72	60	27	9	32.14	11.01	12.73	16.05	20.22
Guasca	84	14	13	6	5	1	15.48	9.19	23.58	25.58	1.45
La Calera	193	15	15	5	4	1	7.77	8.91	5.88	23.94	20.02
El Calvario	55	5	4	4	4	0	7.27	23.75	4.89	1.10	2.10
San Juanito	165	4	4	4	4	0	2.42	18.22	5.54	1.32	5.27
Fómeque	493	8	8	2	2	0	1.62	17.24	37.88	4.72	15.29
Sesquilé	13	0	0	0	0	0	0	3.11	1.76	15.47	1.36
Ubaqué	112	0	0	0	0	0	0	2.72	2.87	5.10	10.33
Total	**1,456**	**183**	**158**	**106**	**57**	**16**	**10.85**	**100**	**100**	**100**	**100**

of different individuals (when individuals were identified, see below) were also considered as independent. The total sampling effort was 17,057 days trap. The data were organized and systematized according to Díaz-Pulido & Payán (2012). Every camera-trapping station was georeferenced and located on the map of the study area (Fig. 1).

Individual identification

Adults individual recognition was made following Zug (2009) and Reyes *et al.* (2017), based on the presence of four key external morphological features (attributes useful for specimens identification): presence, shape and color of facial markings; presence, shape and color of pectoral markings (neck and chest markings); estimated body size; and sex, observed from three different viewpoints along the videos obtained during a bear record. Body size of the specimens was estimated by comparison with a reference object of known size located within the visual field of the camera; sex was determined either based on the specimen's genitalia (when visible) or the presence of reproductive features (*e.g.,* evident pregnancy, turgid mammary glands, presence of cubs). Bear records in which at least three of the four key external features were clear, allowing the correct identification of the individual (Reyes *et al.,* 2017), were considered as effective bear records. Cubs were not identified. Every adult individual identified was given a unique code, or a name if it was recaptured (recaptures being counted just if they were independent records). A capture-recapture history worksheet was elaborated.

Relative abundance and population density estimations

Bears relative abundance was calculated for the whole sampled grids and for every grid following Díaz-Pulido & Payán (2012) as: the independent bear records divided by the total number of mammal records, multiplied by a correction factor of 100. The population density estimation was calculated for the whole sampled grids using the capture-recapture data (taking into account just the effective-independent bear records) in the package SECR (Efford, 2017) at the software R version 3.4.1 (Gentleman *et al.,* 2017), with a buffer value input (required by the package) of 43,336 m, which corresponds to 5 times the diameter of the known male home range of the target species (Castellanos, 2011), following Noss *et al.* (2013). Density is expressed as the number of bears per 100 km^2. Additionally, a circular buffer area was obtained for each grid, with a radius corresponding to the maximum mean distance (MMDM) between inter-grids recaptures (Efford, 2017; Noss *et al.,* 2013) (Table 2), and the possible number of individuals at the sampled zone was obtained with the density estimation and the total buffer area of the sampled grids (excluding the overlapping buffer areas between grids).

Table 2. Number of records per recaptured individuals, inter-grid distances (km), time interval between captures (days) and maximum mean distance moved-MMDM (km) for all inter-grid recaptures.

Individual	Sex	Record times	Maximum distance at inter-grid records (interval of days)	Records per grid			
				Junín	Choachí	Calera	Guasca
Ana	F	2				2	
Nelly	F	2		2			
Teresa	F	2		2			
Yeimy	F	2		2			
José	M	6	26.9 (6); 25.4 (23)	2	4		
David	M	4	26.9 (78); 26.9 (59)	2	2		
Carlos	M	9	26.9 (8)	2	7		
Mauricio	M	2	30.3 (9)		1		1
Nicolás	M	2		2			
Pancho	M	2			2		
Tristar	M	2			2		
Wilson	M	2		2			
Hernán	M	4		4			
Kalú	M	4		4			
Pepe	M	6		6			
Juancho	M	14		14			
Total	**12M:4F**	**65**	**MMDM = 27.22**	**42**	**18**	**2**	**1**

RESULTS

A total of 2,784 native fauna records were obtained, 1,456 corresponding to mammals, 183 for Andean bear specimens, 158 of them independent bear records (at least one hour between records), and 106 effective-independent bear records (also permitting individual recognition) (Table 1). Fifty-seven Andean bear individuals were identified according to key external features, sixteen were recaptured (at the same or different grid), and 4 males moved a maximum mean distance (MMDM) of 27.22 km between inter-grids recaptures (Table 2). Two of the most recaptured individuals show physical problems when they walk: the left hindlimb of "Juancho" (14 captures, Table 2) is totally rigid below the hip, and the hip of "Pepe" (9 captures, Table 2) wobbles persistently.

Relative abundance

The greatest relative abundance of independent bear records regarding mammal records (see methods), were obtained in Choachí (35.90), Junín (32.14) and Guasca (15.48), while intermediate relative abundance were obtained in La Calera (7.77) and El Calvario (7.27), and low relative abundance were obtained in San Juanito (2.42) and Fómeque (1.62). No bears were recorded in Sesquillé and Ubaque. The relative abundance for the whole sampled grids was 10.85 (Table 1).

Population density

There are an estimated 2.9 bears/100 km^2 (2.11-3.99) in the Chingaza massif (Table 3), producing an estimate of 122 individuals for the whole buffer area of the sampled grids (4,215.15 km^2, excluding the overlapping buffer areas between grids). The home range diameter for an Andean bear estimated by the model is 5,453 m (4,691-6,340, Table 3).

Table 3. Adjusted estimates for bear density, capture probability, and home range diameter at the study area.

	Estimate	Standard Error	95% CI
Density (bears/100 km^2)	2.90	0.000047	2.11-3.99
Capture probability	0.00074	0.00015	0.000499-0.00110
Home range diameter (m)	5,453	420	4,691-6,340

DISCUSSION

Relative abundance

The absence of bear records at Sesquilé and Ubaque grids is related to the isolation of these two localities from the rest of the Chingaza mazzif. Local inhabitants from Ubaque report not seeing bears in the last 50 years. Although the Sesquilé grid did not record bears either, evidence of bear activity (not recent) was found within the grid location.

San Juanito, El Calvario, and Fómeque (south-eastern zone of the study area) comprise the largest amount of forests and páramo covers along with the lowest amount of transformed covers (*i.e.,* croplands, pastures) of the whole Chingaza massif, however, they also obtained the lowest relative abundance values (excluding Sesquilé and Ubaque, Table 1). Although the bears surely occupy and use this zone of the Chingaza massif with extensive forests and páramos, it is less likely to obtain a record of the specimens within the sampling grids due to the extensive area in which they can move. On the other hand, Choachí, Junin, Guasca, and La Calera (northern zone of the study area), obtained the highest relative abundance values, and in turn, comprise the lowest amount of forests and páramo covers along with the highest amount of transformed covers of the Chingaza massif (Table 1). The Andean bear is a landscape species, with high home range, high dispersal ability, and large habitat requirements (WCS, 2002; Castellanos, 2011). Thus, as long as there is still connectivity between natural spaces, bears most likely will walk them at some point, as previously reported for the Serranía del Perijá (Rodríguez *et al.,* 2019a), where bears use large and continuous habitats on the Venezuelan slope (where a natural national park prevails), as well as limited, unprotected and highly fragmented habitats on the Colombian slope. Although in this study the sampling grids were always placed into natural spaces, it is not surprising that the Chingaza massif zone where bears are more detected corresponds to a highly anthropized area with less natural covers, as they would be using the natural cover remnants. The northern area of the Chingaza massif is also characterized by a large presence of negative human-bear interactions (Rodríguez *et al.,* 2019b), produced by the permanent encounter between the intense anthropic activities

that take place in this area and the bear's movements through the adjacent natural spaces, which will not stop while there is still some connectivity.

Among the sampling grids, many more males than females were recorded, as previously found by Ríos *et al.* (2007), Zug (2009), Jones (2010), and Viteri (2007) in Bolivia and Ecuador. Most females (with or without cubs) were recorded once, and just four were recaptured (Table 2). This sex disparity in the Chingaza massif could be related to an unequal sex proportion in the sampled population, a sex-biased detectability of the specimens, or wider movements by the more usually captured sex (Jones, 2010; Garshelis, 2011; Foster & Harmsen, 2011; Van Horn & Owen, 2015). According to the latter, the difference between male and female records in the Chingaza massif might be indicating a sex-segregated habitat use, as seen in wild grizzly bears, where the males segregate and the females are elusive during the breeding season, protecting their cubs from intraspecific infanticide by avoiding zones highly frequented by males (Rode *et al.,* 2006; Kendall *et al.,* 2009; Clapham *et al.,* 2012; Steyaert *et al.,* 2013; Lamb *et al.,* 2017). Although more research is needed about this possible sexual segregation in *T. ornatus,* the low records of females accompanied by their cubs at highly male frequented zones, even being previously recorded as pregnant, support such possible sexual segregation in the species.

Population density

The estimated density of 2.9 (2.11 to 3.11) bears/100 km^2 (Table 3) is the first density estimates and the first approach to a population status for Andean bears in Colombia. This density is the lowest regarding all previous published estimates from Bolivia and Ecuador (3-7.45 bears/100 km^2, Ríos-Uzeda *et al.,* 2007; Viteri, 2007; Morrell, 2014; Molina *et al.,* 2017). The temporal and spatial scale of the sampling effort lends credibility to this density estimate for the Chingaza massif. The low bears' density in the Chingaza massif may be due to the high-impact human activities on the landscape, such as the extensive amount of land covers transformed to croplands and livestock pastures (especially at the north of the massif, Table 1), along with the infrastructure construction in and around the massif (*i.e.,* main roads, dams, mines, Rodríguez *et al.,* 2019b), which have drastically transformed the natural areas. These human activities restrict mammal natural displacements (Tucker *et al.,* 2014, 2018), altering the natural dynamics of bears, exacerbating sexual dimorphism as reported by Rode *et al.* (2006) for Grizzly bears in Alaska, and modifying population dynamics, as the negative effect of roads on the Andean bear population densities previously reported by Morrell (2014) in Ecuador. In the case of the Andean bear, limiting its natural displacements affects also a key ecologic feature of the species, when the bears follow the fruiting cycles of different plant resources through the natural spaces as if they would be harvesting (Rodríguez, 1991), thus, not just the population density and persistence itself is affected, but also ecosystem processes like seed dispersal and forest recruitment.

ACKNOWLEDGMENTS

This research was funded by the Empresa de Acueducto de Bogotá – Empresa de Servicios Públicos (EAB-ESP) and the Fundación para la Investigación, Conservación y Protección del Oso Andino "Wii" (Fundación Wii), whithin the project "Conservación, restauración y uso sostenible de servicios ecosistémicos entre los páramos de Guerrero, Chingaza, Sumapaz, los cerros orientales y su área de influencia", co-funded by the Sistema General de Regalías (Royalties General System) and the Secretaría Distrital de Ambiente (Environmental Distrital Secretary). We thank the rural communities of the Chingaza massif, for allowing us to walk their paths and reach their farms, and for sharing with us all their knowledge, especially we thank our field assistants Fredy Saray, Ricardo González, Humberto Gómez, Jorge Armando Vanegas, Omar Iván Sabogal, Nelson Ladino, Omar Urías Vaquero, Jorge Abel Martínez, Oscar Iván Pérez and Bernardo Cifuentes. We also thank the Parque Jaime Duque (Jaime Duque Park) and the Fundación Endémica Estudios (Endemic Studies Foundation) for its helpful support. We are grateful to Russ Van Horn, Mathias Tobler and Ángela Rojas for their timely and accurate observations on the manuscript.

AUTHOR'S CONTRIBUTIONS

Daniel Rodríguez and Adriana Reyes: Conceived and designed the experiments, carried out the experiments, analyzed the data, contributed with analysis tools, wrote the document, prepared figures and/or tables and revised the drafts of the document. Nicolás Reyes-Amaya: Analyzed the data contributed with analysis tools, wrote the document, prepared figures and/or tables and revised the drafts of the document. Camilo Quiñones and Yeimy Castillo-Navarro: Carried out the experiments. Fidel Poveda and Robinson Duque: Revised the drafts of the document.

REFERENCES

Castellanos, A. 2011. Andean bear home ranges in the Intag region, Ecuador. *Ursus,* 22(1): 65-73.

Chávez, C.; de la Torre, A.; Bárcenas, H.; Medellín, R.A.; Zarza, H. & Ceballos, G. 2013. *Manual de fototrampeo para estudio de fauna silvestre. El jaguar en México como estudio de caso.* México. Alianza WWF & Telcel, Universidad Nacional Autónoma de México. 108p.

Clapham, M.; Nevin, O.T.; Ramsey, A.D. & Rosell, F. 2012. A hypothetico-deductive approach to assessing the social function of chemical signaling in a non-territorial solitary carnivore. *PLoS ONE,* 7(4): 1-11, e35404. DOI

Díaz-Pulido, A. & Payán, E. 2012. *Manual de fototrampeo: una herramienta de investigación para la conservación de la biodiversidad en Colombia.* Bogota, Instituto de Investigaciones de Recursos Biológicos Alexander Von Humboldt & Panthera Colombia. 32p.

Efford, M.G. 2017. *Secr: Spatially explicit capture-recapture models. R package version 3.0.1*. https://CRAN.R-project.org/package=secr.

Foster, R.J. & Harmsen, B.J. 2011. A critique of density estimation from camera-trap data. *Journal of Wildlife Management,* 76(2): 224-236.

Garshelis, D.L. 2011. Andean bear density and abundance estimates – How reliable and useful are they? *Ursus,* 22(1): 47-64.

Gentleman, R.; Ihaka, R. & Bates, D. 2017. *The R project for statistical computing*. http://www.r-project.org.

Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM). 2013. *Zonificación y codificación de unidades hidrográficas e hidrogeológicas de Colombia*. Bogotá, D.C. 46p.

Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM). 2014. *Cobertura de la tierra metodología CORINE Land Cover adaptada para Colombia durante el periodo 2010-2012*. Bogotá, D.C., Colombia. Disponível em: http://www.ideam.gov.co/web/ecosistemas/coberturas-tierra.

Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM); Instituto Geográfico Agustín Codazzi (IGAC); Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH); Instituto de Investigaciones Marinas y Costeras (INVEMAR); Instituto Amazónico de Investigaciones Científicas (SINCHI) & Instituto de Investigaciones Ambientales del Pacífico (IIAP). 2007. *Ecosistemas continentales, costeros y marinos de Colombia.* Bogotá. 276p. + 37 hojas cartográficas.

Jaramillo-Robledo, A. & Chaves-Cordoba, B. 2000. Distribución de la precipitación en Colombia analizada mediante conglomeración estadística. *Cenicafé,* 51(2): 102-13.

Jones, T. 2010. *Detection probability and individual identification of the Andean Bear (Tremarctos ornatus) using camera trapping methods.* Msc. Thesis.. Madison, University of Wisconsin. 121p.

Kattan, G.; Hernández, O.L.; Goldstein, I.; Rojas, V.; Murillo, O.; Gómez, C.; Restrepo, H. & Cuesta, F. 2004. Range fragmentation in the spectacled bear *Tremarctos ornatus* in the northern Andes. *Oryx,* 38: 155-163.

Kendall, H.; Stetz, J.B.; Boulanger, J.; Macleod, A.C.; Paetkau, D. & White, G.C. 2009. Demography and Genetic Structure of a Recovering Grizzly Bear Population. *The Journal of Wildlife Management,* 73(1): 3-17.

Lamb, C.T.; Mowat, G.; Gilbert, S.L.; McLellan, B.N.; Nielsen, S.E. & Boutin, S. 2017. Density dependent signaling: An alternative hypothesis on the function of chemical signaling in a nonterritorial solitary carnivore. *PLoS ONE,* 12(10): 1-12, e0184176. DOI

Molina, S.; Fuller, A.K.; Morin, D.J. & Royle, J.A. 2017. Use of spatial capture-recapture to estimate density of Andean bears in northern Ecuador. *Ursus,* 28(1): 117-26.

Morrell, N. 2014. *Conservation planning at multiple scales: A density model and spatial planning tool to facilitate the conservation of Andean bears (Tremarctos ornatus) and the Northern Andes.* B.Sc. Thesis. 90p. The University of British Columbia.

Noss, A.; Polisar, J.; Maffei, L.; García, R. & Silver, S. 2013. *Evaluating jaguar densities with camera traps.* New York, Jaguar Conservation Program & Latin America and Caribbean Program; Wildlife Conservation Society. 79p.

Parque Nacional Natural Chingaza (PNN Chingaza). 2005. *Documento ejecutivo del plan de manejo del Parque Nacional Natural Chingaza 2005-2009*. Bogotá. D.C., PNN Chigaza. 123p.

Parque Nacional Natural Chingaza (PNN Chingaza). 2016. *Reformulación participativa del plan de manejo Parque Nacional Natural Chingaza Parques Nacionales de Colombia.* Bogotá. D.C., PNN Chigaza. 273p.

Peyton, B. 1999. Spectacled bear conservation action plan. *In:* Servheen, C.; Herrero, S. & Peyton, B. (Eds.). *Bears: Status survey and conservation action plan.* Cambridge, UICN/SSC Bear Specialist Group. p. 157-198.

Reyes, S.A.; Rodríguez, E.D.; Reyes-Amaya, N.; Rodríguez-Castro, D.; Restrepo, H. & Urquijo, M. 2017. Comparative efficiency of photographs and videos for individual identification of the Andean bear *(Tremarctos ornatus)* in camera trapping. *Therya,* 8(1): 83-7.

Ríos-Uzeda, B.; Gómez, H. & Wallace, R.B. 2007. A preliminary density estimate for the Andean bear *(Tremarctos ornatus)* in the Bolivian Andes. *Ursus,* 18(1): 124-128.

Rode, K.D.; Farley, S.D. & Robbins, C.T. 2006. Sexual dimorphism, reproductive strategy, and human activities determine resource use by brown bears. *Ecology,* 87(10): 2636-46.

Rodríguez, D.; Reyes, A.; Reyes-Amaya, N.; Gallegos-Sánchez, S.; Gutierrez, J.; Suárez, R. & Prieto, F. 2019a. Northernmost distribution of the Andean bear *(Tremarctos ornatus)* in South America, and fragmentation of its associated Andean forest and Paramo ecosystems. *Therya,* 10(2): 161-170.

Rodríguez, D.; Reyes, A.; Vergel, J.; Rincón, S.; Galindo, M.; González, A.; Zamudio, B.; Camacho-Muete, L.; Quiñones, A.C.; Jaramillo, J.; Rodríguez, S.; Rincón, C.; Mancipe, M.; Castillo, Y.; Rubio, L. del S.; Rivera, F.; Cubillos, A.; Rojas-Rojas, A.; Gómez, I.; Hidalgo, M.; Muñoz, M. & Rodríguez, M. 2019b. *El Macizo Chingaza: Tierra de osos, tierra de gente, tierra de todos. Empresa de Acueducto y Alcantarillado de Bogotá.* Bogota, ESP. 148p.

Rodríguez, E.D. 1991. *Evaluación y uso del hábitat natural del oso andino Tremarctos ornatus (F. Cuvier 1825) y diagnóstico del estado actual de la subpoblación en el Parque Nacional Natural de las Orquídeas.* Antioquia, Colombia. Tesis. Bogotá, Universidad Nacional de Colombia. 134p.

Sguerra, S.; Bejarano, P.; Rodríguez, O.; Blanco, J.; Jaramillo, O. & Sanclemente, G. 2011. Corredor de Conservación Chingaza-Sumapaz-Guerrero. *Resultados del Diseño y Lineamientos de Acción.* Bogotá, Conservación Internacional Colombia & Empresa de Acueducto y Alcantarillado de Bogotá; ESP. 184p.

Steyaert, S.M.J.G.; Kindberg, J.; Swenson, J.E. & Zedrosser, A. 2013. Male reproductive strategy explains spatiotemporal segregation in brown bears. *Journal of Animal Ecology,* 82: 836-845.

Tucker, M.A.; Böhning-G., K.; Fagan, W.F.; Fryxell, J.M.; Van Moorter, B.; Alberts, S.C.; Ali, A.H.; Allen, A.M.; Attias, N.; Avgar, T.; Bartlam-Brooks, H.; Bayarbaatar, B.; Belant, J.L.; Bertassoni, A.; Beyer, D.; Bidner, L.; van Beest, F.M.; Blake, S.; Blaum, N.; Bracis, Ch.; Brown, D.; Nico de Bruyn, P.J.; Cagnacci, F.; Calabrese, J.M.; Camilo-A., C.; Chamaillé-J., S.; Chiaradia, A.; Davidson, S.C.; Dennis, T.; DeStefano, S.; Diefenbach, D.; Douglas-H., I.; Fennessy, J.; Fichtel, C.; Fiedler, W.; Fischer, C.; Fischhoff, I.; Fleming, C.H.; Ford, A.T.; Fritz, S.A.; Gehr, B.; Goheen, J.R.; Gurarie, E.; Hebblewhite, M.; Heurich, M.; Mark Hewison, A.J.; Hof, C.; Hurme, E.; Isbell, LA.; Janssen, R.; Jeltsch, F.; Kaczensky, P.; Kane, A.; Kappeler, P.M.; Kauffman, M.; Kays, R.; Kimuyu, D.; Koch, F.; Kranstauber, B.; LaPoint, S.; Leimgruber, P.; Linnell, J.D.C.; López-L., P.; Markham, A.C.; Mattisson, J.; Medici, E.P.; Mellone, U.; Merrill, E.; de Miranda Mourão, G.; Morato, R.G.; Morellet, N.; Morrison, T.A.; Díaz-M., S.L.; Mysterud, A.; Nandintsetseg, D.; Nathan, R.; Niamir, A.; Odden, J.; O'Hara, R.B.; Oliveira-S., L.G.R.; Olson, K.A.; Patterson, B.D.; de Paula, R.C.; Pedrotti, L.; Reineking, B.; Rimmler, M.; Rogers, T.L.; Rolandsen, C.M.; Rosenberry, C.S.; Rubenstein, D.I.; Safi, K.; Saïd, S.; Sapir, N.; Sawyer, H.; Schmidt, N.M.; Selva, N.; Sergiel, A.; Shiilegdamba, E.; Silva, J.P.; Singh, N.; Solberg, E.J.; Spiegel, O.; Strand, O.; Sundaresan, S.; Ullmann, W.; Voigt, U.; Wall, J.; Wattles, D.; Wikelski, M.; Wilmers, C.C.; Wilson, J.W.; Wittemyer, G.; Zięba, F.; Zwijacz-K., T. & Mueller, T. 2018. Moving in the Anthropocene: Global reductions in terrestrial mammalian movements. *Science,* 359: 466-469. DOI

Tucker, M.A.; Ord, T.J. & Rogers, T.L. 2014. Evolutionary predictors of mammalian home range size: body mass, diet and the environment. *Global Ecology and Biogeography,* 23(10): 1105-1114.

Van Horn, R. & Owen, M. 2015. Could historically advantageous maternal investment by female bears create challenges for conservation breeding efforts? *International Bear News,* 24(1): 34.

Van Horn, R.C.; Zug, B.; Appleton, R.D.; Velez-Liendo, X.; Paisley, S. & LaCombe, C. 2015. Photos provide information on age, but not kinship, of Andean bear. *PeerJ,* 3: e1042. DOI

Van Horn, R.C.; Zug, B.; LaCombe, C.; Velez-Liendo, X. & Paisley, S. 2014. Human visual identification of individual Andean bears Tremarctos ornatus. *Wildlife Biology,* 20: 291-299.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. *The Journal of Wildlife Management,* 47(4): 893-901.

Viteri, M.P. 2007. *Conservation genetics of Andean bears (Tremarctos ornatus) in northeastern Ecuador: Molecular tools, genetic diversity and population size.* Thesis. 77p. University of Idaho. Moscow.

Wildlife Conservation Society (WCS). 2002. Selecting landscape species. *Living Landscapes Bulletin,* 4: 1-4. (Wildlife Conservation Society)

Witmer Gary, W. 2005. Wildlife population monitoring: some practical considerations. *Wildlife Research,* 32(3): 259-263.

Zug, B. 2009. *Individual identification and habitat use of Andean bears on private lands in the Ecuadorian Andes.* Msc thesis. University of Wisconsin. Madison. 106p.

Published with the financial support of the "Programa de Apoio às Publicações Científicas Periódicas da USP"