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Space use by a male Andean bear (*Tremarctos ornatus*) tracked with GPS telemetry in the Macizo Chingaza, Cordillera Oriental of the Colombian Andes

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ABSTRACT
For decades, telemetry has provided large amounts of ecological information for several bear species; however, for the Andean bear (*Tremarctos ornatus*), only three studies have available information. The use of space for this species was measured for the first time in Colombia with a male specimen tracked with GPS telemetry. Bear locations (n= 348) were obtained between October and December 2013, during the dry season. Our dry-season male home range estimates with nearest-neighbor convex-hull (K-NNCH, 24.62 km^2) and kernel density estimate (KDE, 42.15 km^2) slightly exceed those reported for the species in Ecuador, and our minimum convex polygon (MCP, 238.86 km^2) quintupled estimates from Ecuador. This finding supports the hypothesis that more fragmented landscapes demand greater movements to obtain sufficient resources. K-NNCH and KDE were the most accurate methods, as they excluded degraded terrain not used by the tracked bear. Total daily traveled routes oscillated between 0.51-12.07 km. The forest-*páramo* ecotone, full of dry-season-fruiting Ericaceae shrubs, was the main habitat used.

Key words: Andean bear, core area, GPS telemetry, habitat, home range

RESUMEN – Uso del espacio por un oso andino (*Tremarctos ornatus*) macho marcado con telemetría GPS, en el macizo Chingaza, Cordillera Oriental de los Andes colombianos
La telemetría ha proporcionado gran cantidad de información ecológica de varias especies de osos, pero solo tres estudios se han publicado sobre el oso andino (*Tremarctos ornatus*). Se midió el uso del espacio en esta especie para el primer espécimen marcado con telemetría GPS en Colombia. Las posiciones GPS (348) se obtuvieron entre octubre y diciembre de 2013, durante la estación seca. Los rangos de hogar en estación seca para el macho marcado usando casco convexo local del vecino más cercano (K-NNCH 24,62 km2) y estimador de densidad de núcleo (KDE 42,15 km2), excedieron levemente a los reportados para la especie en Ecuador, y el rango de hogar en estación seca usando polígono mínimo convexo (MCP, 238,86 km2) quintuplicó la de estudios previos en Ecuador. Esto apoyaría la hipótesis de que paisajes más fragmentados demandan mayores movimientos para obtener suficientes recursos. Los métodos más precisos fueron K-NNCH y KDE, excluyendo de sus cálculos terrenos degradados no utilizados por el oso. Las rutas diarias totales oscilaron entre 0,51-12,07 km. El principal hábitat utilizado fue el ecotono entre páramo y bosque, lleno de arbustos de ericáceas que fructifican en la estación seca.

Palabras clave: área núcleo, hábitat, oso andino, rango de hogar, telemetría GPS

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Wildlife use of space reflects the animals' cognitive map of their environment, which may vary depending on spatial and temporal variables such as habitat availability (Börger et al. 2008; Powell & Mitchell 2012). Telemetry has improved our knowledge on the spatial ecology of wildlife, such as home range (traversed area during animal normal activities; Burt 1943) and core area (an animal most heavily used area; Kernohan et al. 2001), which are useful for wildlife management and conservation (Millspaugh & Marzluff 2001; Kays et al. 2015). Although telemetry has provided a great amount of ecological information on several bear species (Garshelis 2004; Heard et al. 2008; Evans et al. 2012; Zeller et al. 2020), only a few studies have been developed for the threatened Andean bear *Tremarctos ornatus* (Cuvier, 1825) in Bolivia and Ecuador, with only the studies in Ecuador addressing home range and core area (Castellanos 2011, 2013; Paisley & Garshelis 2006; Velez-Liendo & García-Rangel 2017).

Considering the importance of reliable ecological information for the conservation of this species, which has different habitat characteristics across its natural distribution, we provide data on the first Andean bear tracked with a GPS collar in a fragmented landscape in Colombia.

The study area is located between 2,241 and 3,980 m a.s.l. in the Macizo Chingaza, on the Cordillera Oriental (Eastern Range) of the Colombian Andes in both Cundinamarca and Meta departments, including from lower to upper: montane Andean forests, high Andean forest, *subpáramo* shrublands, and *páramo* shrublands and grasslands (PNN Chingaza 2005). A unimodal rainfall regime occurs in the Chingaza massif, influenced by eastern trade winds, with a peak between May and August, and the lowest precipitations between December and February (IDEAM 2013).

The adult male Andean bear (130 kg) was captured in an Iznachi® trap and immobilized with darts containing a mixture of Ketamine hydrochloride (3–8 mg/kg) and Xylazine (2 mg/kg) following Castellanos et al. (2010), and according to the American Society of Mammalogists Guidelines (Sikes & Animal Care and Use Committee of the American Society of Mammalogists 2016). A veterinary evaluation of specimen health was made, including blood samples, and morphometric measurements were also taken. Finally, the individual was fitted with an Advanced Telemetry Systems (ATS®) dual VHF-GPS telemetry collar (model G2110E). The bear was followed for two days in the field using the homing technique (Millspaugh & Marzluff, 2001) to determine its successful recovery after the intervention procedure.

The GPS positions obtained from the telemetry collar were used to calculate spatial use measures using the adehabitatHR package (Calenge 2015) on R v.3.4.1 (R Core Team 2019). Home range and core area measures were obtained with minimum convex polygon (MCP) using 100% and 50% of locations (Mohr 1947), kernel density estimate (KDE) using 95% and 50% of locations, least-squares cross-validation bandwidth estimator (Worton 1989), and nearest-neighbor convex-hull (K-NNCH) using 100% of locations and a nearest neighbor "k" parameter of 6 (Getz & Wilmers 2004), following Castellanos (2011, 2013). Since the selected estimation methods are robust dealing with both independent and auto-correlated data sets, independence analyses between locations were not performed (De Solla et al. 1999; Kernohan et al. 2001; Fieberg 2007).

Home range and core area polygons were plotted on to a map of the study area including natural covers, based on Landsat, Rapid Eye, and Spot satellite images from 2010–2012 with 30 m of resolution, extracted from the Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia (IDEAM 2014) (Figs. 1, 2). The established habitat types were Andean and high-Andean forest (including the Corine Land Cover types dense high forest, dense low forest, and fragmented forest), *páramo* and *subpáramo* shrublands (open bushes and dense bushes), *páramo* grasslands (dense grassland), and livestock pastures (clean pastures). Since the tracked bear showed a diurnal activity pattern (see Rodríguez et al. 2016), habitat use was analyzed assessing the number of positions per coverage category during the day (5:00–18:00, bear active) and night (19:00–4:00, bear not active). Finally, the daily movements (distances traveled) of the specimen were reported as the sum of the linear distances (km) between locations obtained across a 24 hr (0:00–24:00) period.

A total of 348 GPS bear locations were obtained during part of the dry season (October–December 2013) before the telemetry collar stopped working (Rodríguez et al. 2016). Regardless of the estimation method, all dry-season home range and core area measures were larger than those of previous studies on this species in Ecuador (Castellanos 2011, 2013) (Table 1). The use of space by a species can vary according to habitat availability and fragmentation (Börger et al. 2008; Powell & Mitchell 2012), for example, for studies on small and medium-sized mammals (Andreassen et al. 1998; Verbeylen et al. 2009; Mergey et al. 2011). Places with less natural coverage demand greater movements to obtain enough resources, leading to larger home ranges (Ofstad et al. 2016). The Chingaza massif is characterized by high-impact human activities at the landscape level, including significant land cover transformation to croplands and livestock pastures, along with the infrastructure construction (i.e., main roads, dams, mines) in and around the massif, which have drastically transformed the natural areas (Rodríguez et al. 2020).

Our results show that the MCP dry-season home range (238.86 km^2; Fig. 1A) was the most different regarding that reported in Ecuador, quintupling it (Table 1). The KDE dry-season home range (98.58 km^2; Fig. 1B) and core area (20.91 km^2; Fig. 1B) measures slightly exceed and doubled those of Ecuador, respectively. The K-NNCH dry-season home range (29.62 km^2; Fig. 2) slightly exceeds that of Ecuador (Table 1). The MCP is the oldest and simplest method for estimating home range, creating polygons with the outer-most locations of the data set (Kernohan et al. 2001; Powell & Mitchell 2012). The K-NNCH method constructs small convex hulls with each relocation and its nearest neighbors (defined by a nearest-neighbor “k” parameter) and merge those hulls from smallest to largest into isopleths (Getz & Wilmers 2004), quite similar to MCP but using various subsets of locations. Finally, KDE is a probabilistic method that implements the utilization distribution (i.e., the density of locations) to determine an animal’s probability of occurrence in the space (Worton 1989; Kernohan et al. 2001; Powell & Mitchell 2012). The KDE and K-NNCH analyses are less sensitive than MCP to overestimate home range polygons (Kernohan et al. 2001). In this study, MCP was the only method that completely encompasses the limestone open-pit mine "El Palacio" (Fig. 1A). Although this open-pit mine has been closed since the 1990s, its extremely degraded soils are not suitable Andean bear habitat and indeed has no bear locations. Thus, we consider KDE and K-NNCH results as more accurate.

During the day (bear active) and from 227 GPS locations obtained, 25.55% were located within the Andean and high-Andean forests, at altitudes between 2,067 and 3,463 m, 62.56% were located in the *páramo* and *subpáramo* shrublands at altitudes between 3,070 and 3,632 m, 10.57% were located in the *páramo* grasslands at altitudes between 3,248 and 3,645 m, and 1.32% were located within livestock pastures at altitudes between 3,146 and 3,357 m. Likewise, from 121 nocturnal (bear not active) GPS locations, 31.40% were located in the Andean and high-Andean forests at altitudes between 3,017 and 3,394 m, and 68.60% were located within *páramo* and *subpáramo* shrublands at altitudes between 3,117 and 3,637 m. The male Andean bear preferred the *páramo* and *subpáramo* shrublands, followed by the Andean and high-Andean forest, for both diurnal displacements and nocturnal resting places, suggesting an intense use of the *páramo*-forest ecotone, which during the dry-season included many fruiting Ericaceae shrubs *Macleania rupestris* and *Cavendishia bracteata* (Fernández 2012), reported as part of the Andean bear diet (Figueroa 2013).

Previous studies stated that Andean bears prefer Andean forests, but use the *páramo* when it is present (Peyton 1980; Yerena 1987; Rodríguez 1991; Ríos-Uzeda et al. 2006; Rodríguez et al. 2019). However, our results suggest that at least in the dry season in the Chingaza massif, Andean bears can intensively use the *páramo/subpáramo* shrublands. Finally, the daily distance traveled of the tracked Andean bear varied between 0.51 km and 12.07 km, with an average of 3.39 km (SD 2.29).

Data from various individuals for longer periods are needed to completely understand the use of space by Andean bears; however, the information obtained from the Chingaza massif is a valuable contribution to Andean bear ecological knowledge, which will be useful for management and conservation.

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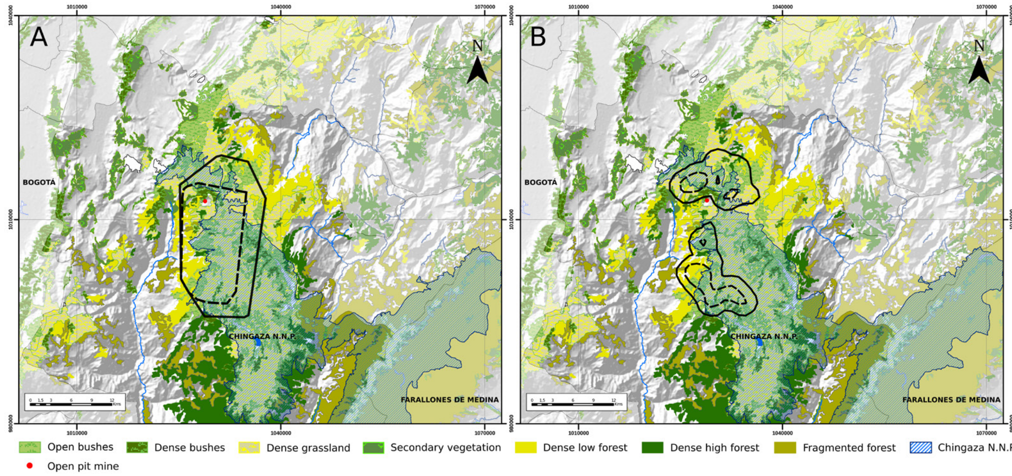

Figure 1. Home range and core area estimates for a male Andean bear in Chingaza, Colombia. A: Minimum convex polygon 100% (continuous line) and 50% (dashed line); B: Kernel density estimate 95% (continuous line) and 50% (dashed line).

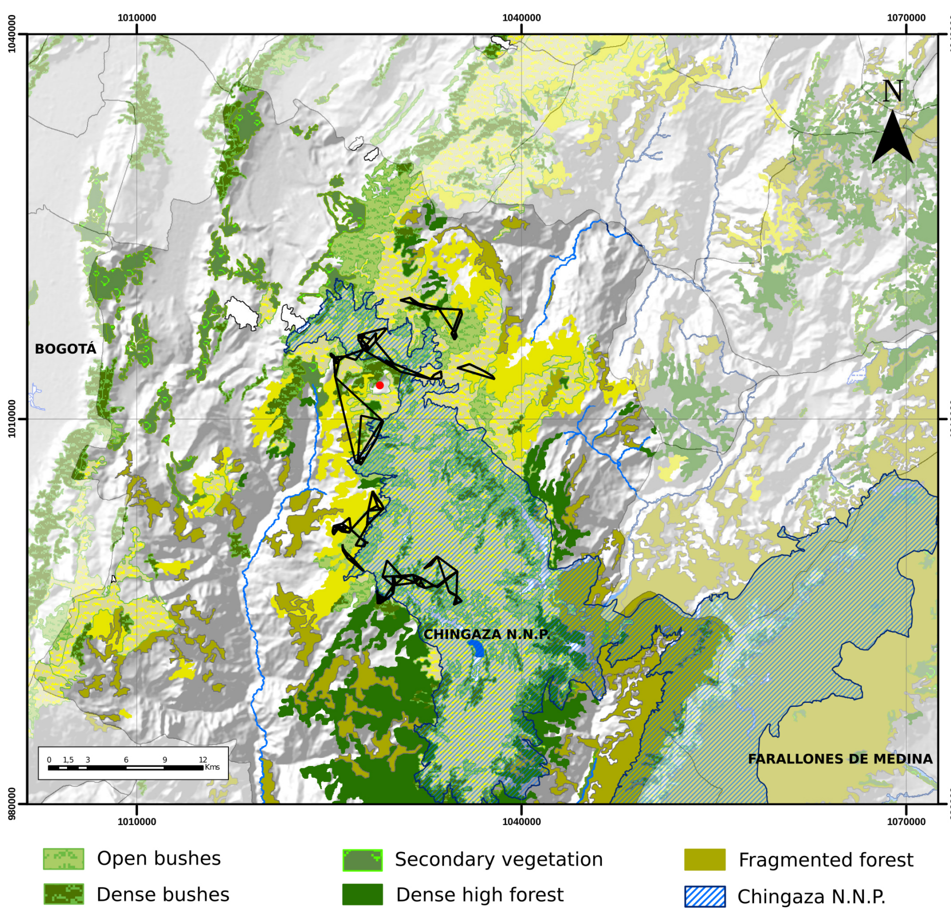

Figure 2. Nearest-neighbor convex-hull home range estimate for a male Andean bear in Chingaza, Colombia.

Table 1. Andean bear home range estimates from this study in Chingaza (Colombia) and Castellanos (2011, 2013) in Ecuador. Abbreviations: MCP, minimum convex polygon; KDE, kernel density estimate; K-NNCH, nearest-neighbor convex-hull. When available, standard deviations (SD) are presented in parentheses.

			MCP 100%	MCP 50%	KDE 95%	KDE 50%	K-NNCH 100%
Castellanos (2011, 2013)	Dry season	Male	46.9 (11.73)	-	86.07	12.95	27.44 (21.72)
		Female	22 (16.08)	-	18.53	1.57	6.85 (4.03)
	Wet season	Male	92.85 (62.38)	-	105.21	14.86	22.52 (9.42)
		Female	31.93 (20.12)	-	18.5	3.39	9.51 (5.66)
	Annual	Male	125.8 (48.61)	-	157.05	23.89	59.08 (4.33)
		Female	36.2 (16.31)	-	20.03	2.23	14.77 (5.35)
This study	Dry season	Male	238.86	140.38	98.58	20.91	29.62

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