Andean bear home ranges in the Intag region, Ecuador

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Abstract: I estimated home ranges of 5 female and 4 male Andean bears (*Tremarctos ornatus*) inhabiting the Intag region in Ecuador between September 2001 and December 2006, using 1,439 and 412 telemetry locations for females and males, respectively. Multi-annual and seasonal home ranges were estimated using 2 methods: minimum convex polygon (MCP) and nearest-neighbor convex hull (k-NNCH) analyses. I considered k-NNCH analysis the best method for estimating Andean bear home ranges in fragmented landscapes such as those across the study site. Annual home range of males (59 km^2) were larger than those for females (15 km^2) using the k-NNCH method. During the rainy season home ranges of males were 23 km^2 versus 10 km^2 for females, and in the dry season, 27 km^2 versus 7 km^2. All bears in this study showed some degree of home range overlap, indicating intra-specific tolerance. The mean annual k-NNCH home range of males overlapped home ranges of females by 32%, and among females, overlap was 22%. No evidence of territorial behavior was observed in this study.

Key words: Andean bear, Ecuador, home range, Intag region, nearest-neighbor convex hull method, radio telemetry, *Tremarctos ornatus*

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Because of the inaccessibility of Andean bear (*Tremarctos ornatus)* terrain and the species' elusive nature, scientific data on its ecology are still relatively rare. Due to widespread deforestation throughout South America, Andean bear habitat is being lost and fragmented (Castellanos et al. 2010a). Additionally, in Ecuador many Andean bears are killed in human–bear conflicts (Castellanos 2004). Because of these 2 factors, Andean bears are declining over their entire range. Consequently, the Andean bear is classified on the Red List as vulnerable (VU) across its entire range (International Union for Conservation of Nature 2009) and endangered (EN) in Ecuador (Red Book of Mammals of Ecuador [Cuesta and Suarez 2001]); it is also included in Appendix I of the Convention on the International Trade of Endangered Species (CITES).

Very little is known about the home range and movements of wild Andean bears. Although radiotelemetry has long been used to study life-history strategies of other bear species, this technology has often been considered impractical for researchers of Andean bears, due to the complex topography, altitude, and dense vegetation across most of the species' range (Paisley and Garshelis 2006). Andean bears have also proven difficult to capture for radiotelemetry because of their timid nature and avoidance of human contact. Once captured, no Andean bear in Ecuador has been known to have entered the same type of trap again (Castellanos 2010).

The first studies to radiotrack Andean bears were carried out by Castellanos (1996; A. Castellanos, 2001, Ecología del comportamiento de osos Andinos reintroducidos y silvestres en la Reserva Alto Chocó, Ecuador, unpublished report to the World Society for the Protection of Animals, London, UK) who reported home ranges and activity patterns of 7 reintroduced bears in northwest Ecuador. Two wild Andean bears were subsequently radiocollared in Apolobamba, Bolivia, providing the first data on the movements of wild Andean bears (Paisley 2001, Paisley and Garshelis 2006). Such data are vital for understanding the behavior and ecology of the species, and should contribute to the success of Andean bear reintroductions by helping to identify release sites and their optimum sizes.

I began radiotracking bears in northwest Ecuador in 2001. I report here on radiotelemetry data obtained from 9 wild Andean bears between 2001 and 2006. My objectives were to: (1) estimate the annual and seasonal home ranges of male and female Andean bears across the Intag region of Ecuador,

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Fig. 1. Location of the study area in the Intag Region in northwest Ecuador to determine home range size and overlap for the Andean bear.

and (2) estimate the annual and seasonal home range overlap among collared bears within the study site.

Study area

The study was carried out between September 2001 and December 2006 in the Intag region, Imbabura Province, Ecuador (Fig. 1). This area is part of the Ecuadorian Chocó, one of the 10 most important biological hotspots on the planet (Myers 1988). The Intag region is in the buffer zone for the 243,638 ha Cotacachi-Cayapas Biological Reserve (Ministerio del Ambiente del Ecuador 2007). The study area was not delimited by me but dictated by the movements of the bears and eventually encompassed approximately 40,000 ha in 3 vegetation zones: cloud forest, high montane forest, and páramo, ranging from 2,000 to 4,000 m (Ministerio del Ambiente del Ecuador 2007).

Due to the wide altitudinal range, a number of microclimates are present across Intag, although 2 main climate types have been identified: equatorial high montane (mean annual temperature 6–12°C) and equatorial mesothermic semi-humid (mean annual temperature 12–20°C). Total annual rainfall ranges between 1,000 and 2,000 mm, and relative humidity is permanently above 80% (Ministerio del Ambiente del Ecuador 2007). Rains occur mostly between October and May and are followed by a dry season from June to September (Castellanos 2004).

In addition to being inhabited by Andean bears, the cloud forests of Intag are one of the last refuges for species such as small ocelot (*Leopardus tigrinus*), Quichuan porcupine (*Coendou quichua*), pacarana (*Dinomys branickii*), cock of the rock (*Rupicola peruvianus*), laminated toucan (*Andigena laminirostris*), and toucan barbet (*Semnornis ramphastinus*), which are threatened with extinction primarily due to deforestation for agricultural purposes. Since the 1960s, a large portion of native forest in the western Andes has been destroyed, leaving an estimated less than 8% remaining (Dodson and Gentry 1993, Ministerio del Ambiente del Ecuador 2007). Consequently, it is one of the most heavily deteriorated ecosystems on the planet (Sierra 1999). Maize production is one of the main human activities in Intag, leading to human–bear conflicts.

Methods

Andean bears were captured during September 2001–September 2006 using Iznachi traps (Castellanos 2002). Each captured bear was immobilized using darts launched from a blowpipe or a plastic tube, or from an air pistol (Telinject®, Romerberg, Germany). The majority of the bears were immobilized using a mixture of ketamine hydrochloride (3–8 mg/kg, Ketamine 50®, Holliday-Scott S.A., Buenos Aires, Argentina) and xylazine hydrochloride (2 mg/kg, Xylazine HCl Injection®, Phoenix Scientific Inc, St. Joseph, Missouri, USA), with yohimbine hydrochloride (0.1–0.25 mg/kg, Reverzine S.A.®, Parnell Laboratories, Alexandria, New South Wales, Australia) used as the reversing agent. Some bears were tranquilized using equal parts tiletamine hydrochloride and zolazepam hydrochloride (Zoletil®, Virbac S.A, Carros Cedex, France) at dosages of 3–5 mg/kg body weight (Castellanos et al. 2010b).

Immobilized bears were weighed, measured, and released after being fitted with radiocollars (Model 500 Telonics, Inc., Mesa, Arizona, USA) transmitting at 148–150 megahertz. Bears were tracked for 6–8 hours/day during daylight hours (0600–1830). They were located using a radio receiver TR-2 (Telonics Incorporated, Mesa, Arizona, USA) and a hand-held RA-14K rubber H directional antenna (Telonics Incorporated, Mesa, Arizona, USA).

Tracking expeditions were planned in concordance with data collected on previous days, which enabled continuity in data collection for bears recently located and provided an indication of potential tracking routes for bears that had been out of signal range for long periods. Generally, 2 tracking groups were dispatched, sharing the tasks of daily monitoring of bears within signal range and searching for far-ranging males. At least one 4-day camping trip was organized most weeks into remote areas in search of missing bears. Due to the complex topography, the bears could have been geographically very close to the researcher, but still out of signal range. For this reason I do not consider it meaningful to calculate the percent of time in which the bears could not be located.

I located bears using ground triangulation (White and Garrott 1990) from at least 3 geo-referenced points, separated from each other by a walk of approximately 20 minutes. Some locations were determined from sightings in the field or evidence left in maize fields; these were recorded in situ using a mobile GPS unit (Garmin®, Olathe, Kansas, USA). I plotted all bear locations on a 1:25,000 topographical map and assigned coordinates based on the universal transverse Mercator system (UTM).

I calculated annual and seasonal home ranges using 2 methods: (1) minimum convex polygon 100% (MCP), and (2) nearest-neighbor convex hull (k-NNCH; Mohr 1947, Getz and Wilmers 2004). I used ArcView GIS 3.2a (Environmental Systems Research Institute, ESRI, Redlands, California, USA) and the extension Animal Movement (Hooge et al. 1999) to estimate the MCP, and the extension local convex hull (LOCOH) to calculate k-NNCH (Getz and Wilmers 2004). To decrease data dependency, I used only one location per day to estimate home ranges.

In home range analysis, an asymptotic relationship between home range area and the number of fixed locations is reached when this location number exceeds a certain figure. Recommendations for the number of locations needed vary, but based on work by Belant and Follmann (2002) and Collins et al. (2005), I chose a minimum of 50 locations. Consequently I eliminated bears that had fewer than 50 locations per season or per year from the respective section of the statistical analysis. Only animals monitored for at least an entire year were included in estimates of annual home ranges. I calculated home range overlap as the mean percent that each bear's range overlapped those of all the other bears in the statistical analysis.

Both annual and seasonal data were based on locations compiled throughout the 5-year study. I compiled multi-year data due to the lack of annual data to perform individual yearly analysis, and on the observation that bear home ranges appeared relatively consistent for bears tracked over multiple years. I used *t*-tests (Statistica, StatSoft Inc., Tulsa, Oklahoma, USA) to evaluate differences between males and females for annual and seasonal home range sizes.

Results

Twelve Andean bears (6 males and 6 females) were captured (Table 1). A total of 1,439 locations for females and 412 for males were obtained between September 2001 and December 2006. However, some individuals were excluded from the analyses because of lack of sufficient radiolocations, resulting in final sample sizes of 4 males and 5 females. One male was excluded from the dry season analysis due to lack of data points for this part of the year, and another male was excluded for both wet and dry seasons. Thus, data from 3 males were analyzed for annual home range, from 3 for wet season home range, and from 2 for dry season home range.

For female bears, I received a relatively constant influx of tracking data on a daily basis. For the males, data influx was sporadic as the males moved in and out of signal range, sometimes for weeks at a time.

Home range sizes

The mean annual home range for males using the MCP method was 126 km^2, nearly 4 times larger than the 36 km^2 for females ($t = 3.91$; 7 df; $P = 0.006$; Table 2). Using the k-NNCH method, the mean annual home range for males was 59 km^2, again nearly 4 times larger than the 15 km^2 for females ($t = 12.04$; 6 df; $P < 0.001$; Fig. 2). Mean home range for males exceeded that for females during the wet season (22.52 versus 9.51 km^2; $t = 2.49$; 6 df; $P = 0.04$) and during the dry season (27.44 versus 6.85 km^2; $t = 2.17$; 6 df; $P = 0.072$).

Home range overlap

All individuals showed some annual and seasonal overlap with other radiocollared bears (Table 3, Fig. 2). Using the k-NCCH estimate, males had a mean annual home range overlap with other males

Table 1. Periods tracked, reasons for discontinuing tracking, and number and timing of radiolocations for Andean bears captured and tracked in Intag Region, Ecuador (2001–06) for 412 radiolocations for males, 1439 for females, and 1851 total.

	Dates	Period (months)	Reason for discontinuing tracking	Number of radiolocations Total	Annual	Wet season	Dry season	Age
Males								
Ezequiel	Mar–Dec 2003	9	collar spacer rotted, collar fell off		101	51	50	adult
Pancho	May 2003–Jun 2004	13	collar spacer rotted, collar fell off		133	78	55	sub adult
Juanito	March 2004–April 2005	13	collar slipped off		51	41	10	adult
Jaime	March 2004–Dec 2006	21	battery expired		127	83	44	adult
Alvaro	Mar–Mar 2006	-	bear was shot and killed		-	-	-	adult
Fernando	Sep–Dec 2006	3	unable to triangulate data		-	-	-	sub adult
Females								
Marjory	Sep 2001–Mar 2003	18	battery expired		249	65	184	adult
Porraca	Jan 2002–Oct 2006	57	collar fell off when fixing rotted		553	121	432	sub adult
Dolores	Oct 2002–Jan 2005	27	collar fell off when fixing rotted		330	263	67	adult
Amanda	May 2003–Mar 2005	22	battery expired		146	58	88	adult
Fiona	Apr 2005–Dec 2006	20	battery expired		134	80	54	sub adult
Carolina	May–Dec 2006	7	fewer than 50 radiolocations		27	9	19	sub adult

of 17% (19% during the rainy season and 15% in the dry season). The mean annual overlap of female ranges by male ranges was 32% (34% during the dry season and 29% in the wet season). The mean annual overlap of male ranges by female ranges was 8.5% (9% in the wet season and 8% in the dry season). Among female home ranges, a mean annual overlap of 22% was observed (29% during the wet season and 16% in the dry season).

Discussion

I found the k-NNCH to be the best method for delineating areas inhabited and traversed by bears in this fragmented landscape. In contrast to the MCP method, it eliminates areas not used by bears such as villages and large open pastures (Fig. 3). In addition, k-NNCH isopleths converge to the true area represented by the data as the number of locations increases (Getz and Wilmers 2004), so the method is well suited to this study which has a significant number of data points collected over an extended time.

Table 2. Mean seasonal and annual home range (SD) in km^2 for female and male Andean bears in Intag Region, Ecuador (2001–06).

	Dry season ($n = 5$ F, 2 M) (Jun–Sep)	Wet season ($n = 5$ F, 3 M) (Oct–May)	Annual ($n = 5$ F, 3 M)
Total home range (minimum convex polygon MCP 100%)			
Females	22 (16.08)	31.93 (20.12)	36.2 (16.31)
Males	46.9 (11.73)	92.85 (62.38)	125.8 (48.61)
Total home range (nearest-neighbor convex hull - k-NNCH)			
Females	6.85 (4.03)	9.51 (5.66)	14.77 (5.35)
Males	27.44 (21.72)	22.52 (9.42)	59.08 (4.33)

Home range sizes

Mean annual home range of male Andean bears was significantly (~4x) larger than females, as found in other bear species (Amstrup and Beecham 1976, Dahle and Swenson 2003, Garshelis 2009), as well as in reintroduced Andean bears (Castellanos 1996). Larger male home ranges could result from males searching for sufficient food to sustain a larger body, or from searching for potential mates (Stirling and Derocher 1990, Powell et al. 1997, Dahle and Swenson 2003). Stirling and Derocher (1990) suggested that the larger body size of male ursids relative to females may have evolved in part to favor the establishment of larger home ranges and a subsequent increase in potential mates. It is possible that, for Andean bears, home ranges of males are larger than those of females primarily because males are seeking females in estrus and perhaps secondarily to meet their alimentary needs. This would be in accordance with the opinion of Dahle and Swenson (2003), who noted that home ranges for Scandinavian brown bears (*Ursus arctos*) are also significantly larger than predicted from metabolic needs in males relative to females and concluded that the larger home ranges of males are due to the polygynous

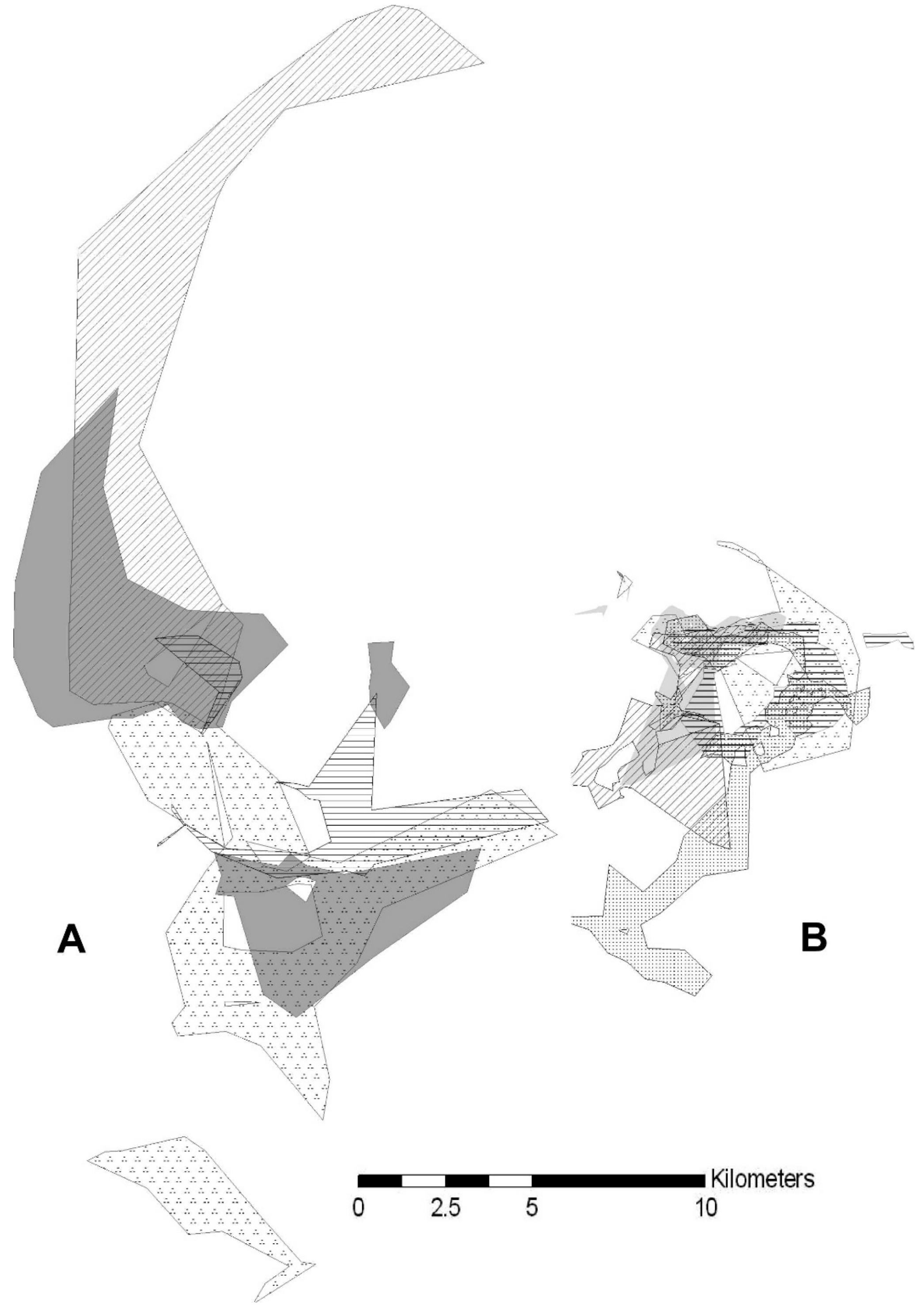

Fig. 2. Male (A) and female (B) home ranges nearest neighbor convex hull (k-NNCH) of Andean bears in Intag Region, Ecuador (2001–06). Each different style of polygon represents an individual bear.

Table 3. Annual and seasonal home range overlap (%) of 9 Andean bears in Intag Region, Ecuador (2001–06), using the nearest-neighbor convex hull (k-NNCH) estimator.

	Dry season (Jun–Sep)	Wet season (Oct–May)	Mean annual
Male–male	15	19	17
Male–female[a]	34	29	32
Female–male[b]	8	9	8.5
Female–female	16	29	22.5

[a]% of home ranges of females which are overlapped by home ranges of males.
[b]% of home ranges of males which are overlapped by home range of females.

mating system, rather than sexual size dimorphism and the metabolic hypothesis.

Castellanos (1996) reported home range sizes for 2 reintroduced Andean bears of 61 km^2 and 4.1 km^2 for the male and female, respectively, using the MCP method. These sizes are smaller than reported in this study, but those animals were tracked for only 8 months, and the home range sizes would have almost certainly increased if they had been followed for a longer period. The 61-km^2 male range was similar to seasonal MCP ranges of wild bears observed in this study, but the range of the reintroduced female was notably smaller than that of wild females.

The mean home range sizes for males in this study using MCP were also considerably larger than that reported by Paisley (2001), who obtained a mean of 7 km^2 for 2 male bears (1 adult and 1 subadult) in a cloud forest–paramo mosiac in northern Bolivia. However, Paisley (2001) could not locate these bears on a substantial number of her radiotracking attempts, in the same way that the males in my study disappeared for extended periods. In addition, Paisley tracked the 2 bears over 13 and 11 months and collected fewer than 80 data points for each bear, suggesting an almost certain underestimate of the actual home range.

In my study, almost all radiotracking attempts for female bears produced an audible radio signal. In the case of the male bears, however, there were periods when no signal was heard, sometimes for weeks at a time. Moreover, I often failed to achieve accurate triangulations. In addition to the real absence of bears from the area, this was likely due to 2 factors: signal bounce and obstructions caused by the mountainous topography characteristic of the study area, meaning that bears could be relatively close to researchers without there being an audible signal; or, when a signal was received, an accurate triangulation could not be achieved because of the time lapse between readings (while traveling on foot between designated listening stations) and the simultaneous movements of bears. Thus, while I believe that the mean home range estimates for female Andean bears in the Intag region are reasonably accurate, I believe that the estimates for male Andean bears are biased low.

Home range overlap

Studies on other bear species all report some degree of overlap of home range between conspecifics (Servheen 1983, Schaller et al. 1985, Joshi et al. 1995). My results also indicate a certain level of intraspecific tolerance among collared bears. However, annual and seasonal male home range overlap was low, indicating that the sampled males had little contact with each other. This could reflect avoidance of potentially dangerous confrontations as reported by Powell et al. (1997) for American black bears (*Ursus americanus*) and Garshelis (2009) for various bear species.

The amount of home range overlap among males and among females was only slightly different. I observed no conclusive evidence of territorial behavior between conspecifics in this study, similar to the findings reported for other bear species (Servheen 1983, Powell et al. 1997, Garshelis 2009). One example of intraspecific tolerance found in this study was the sighting of up to 4 bears of diverse body sizes eating in the same maize field or wild fig tree (*Ficus cuatrecasana*). This behavior was reported by Peyton (1999) and Castellanos (2010). Similarly, S. Molina reported that 15 different Andean bears were identified from camera trap photos feeding on wild avocadoes (*Nectandra* spp.) in an area of 200 hectares within 6 weeks in the Maquipucuna cloud forest reserve of northwest Ecuador (S. Molina, Bear Biologist Maquipucuna Reserve, Ecuador, personal communication, 2009).

It is worth reiterating that the bears included in this study only account for a fraction of the actual population in the study area. For this reason, the results presented here serve only to indicate that intraspecific tolerance exists and cannot reliably indicate the levels of overlap. Future investigations studying all the bears in one area are needed for more accurate mean home range overlap estimates.

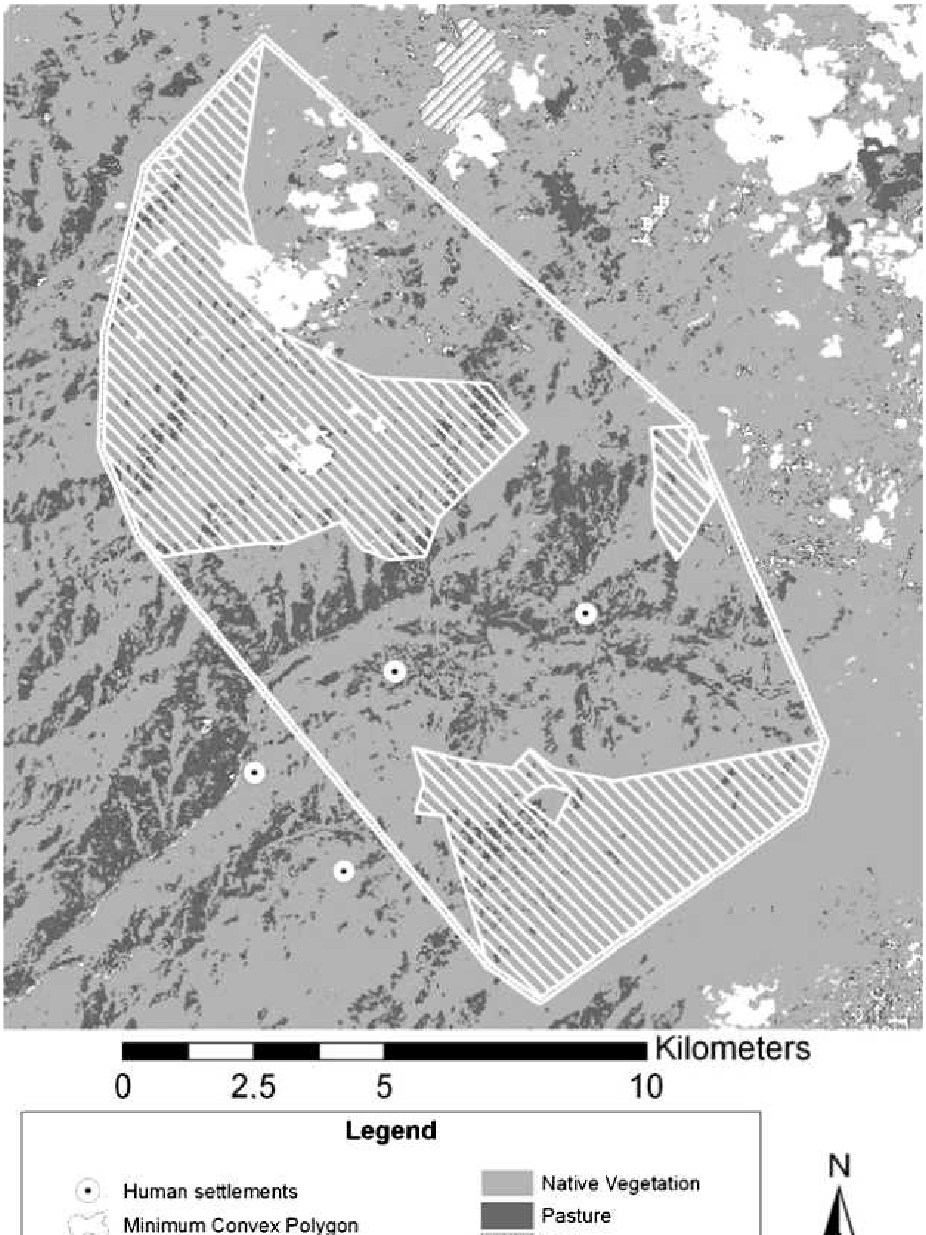

Fig. 3. Map of the home range of a male Andean bear, Intag Region, Ecuador (2004–06), showing how the nearest neighbor convex hull (k-NNCH) method of data analysis excludes areas of human settlement which are included in the home range defined by the minimum convex polygon (MCP) method.

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