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Running Head: Andean bear population in Peru

Title: An Andean bear population hotspot in Northern Peru

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Abstract: Peru is probably home to the largest population of Andean bears (*Tremarctos ornatus;* Peyton 1999); however, no studies have assessed the density and ecology of the species in this region in the past 20 years. Population density estimates are a cornerstone in species conservation by guiding decision-making and monitoring species trends. Here, we study Andean bear population density in a small area (i.e., visible area: 352 ha), Copal, in the Amazonas region in Peru between 2015 and 2017. To estimate Andean bear density, we used 3 methods: 1 based on capture–recapture data of bears, 1 based on an occupancy model, and 1 based on the frequency of a uniquely colored bear compared with the frequency to other black Andean bears. Our results estimated Andean bear densities between 8.85 and 17.39 bears/100 km^2; we considered our estimate of 10.38 bears/100 km^2 from capture–recapture data to be the most reliable. We also recalculated Andean bear density results from Ecuador by Molina et al. (2017), which provided a similar estimate of 11.49 bears/100 km$^{2.}$. Additionally, we report a unique finding of a bear with a golden brown pelage, which we suspect to be the first case in Andean bears. During behavioral observations, Andean bears were predominantly feeding. We suggest that, although Andean bears have large home ranges, a few small areas may be of disproportionate importance to a population. Protecting small areas frequently used by a large number of bears could be an effective mean for Andean bear conservation where large reserves are not a feasible option. We also recognize the need for large-scale studies using a spatial capture–recapture framework, and to associate the results of Andean bear density with resource use in order to successfully protect high-value Andean bear habitat.

Perú probablemente alberga la mayor población de osos andinos (*Tremarctos ornatus*),

sin embargo, ningún estudio ha evaluado la densidad y ecología de la especie en esta región en los últimos 20 años. Las estimaciones de densidad de población son una piedra angular en la conservación de especies al guiar la toma de decisiones y monitorear las tendencias de las especies. En este estudio evaluamos la densidad de población de osos andinos en un área pequeña (área visible: 352 ha), Copal, en la región de Amazonas en Perú. Para estimar la densidad de osos andinos, usamos 3 métodos; 1 basado en datos de captura–recaptura de osos, 1 basado en un modelo de ocupación y 1 basado en la frecuencia de un oso de color único en comparación con la frecuencia de otros osos negros andinos. Nuestros resultados estimaron densidades de osos andinos entre 8.85–17.39 osos/100 km^2; consideramos que nuestra estimación de 10.38 osos/100 km^2 a partir de datos de captura–recaptura es la más fiable. También recalculamos los resultados de densidad de osos andinos de Ecuador por Molina et al. (2017), que proporcionó una estimación similar de 11.49 osos/100 km^2. Además, informamos un hallazgo único de un oso con un pelaje marrón dorado, que sospechamos es el primer caso en osos andinos. Durante las observaciones de comportamiento, los osos andinos pasaban más tiempo alimentándose que realizando otra actividad. Sugerimos que, aunque los osos andinos tienen grandes áreas de distribución, algunas áreas pequeñas pueden tener una importancia desproporcionada para una población. La protección de áreas pequeñas frecuentemente utilizadas por un gran número de osos podría ser un medio eficaz para la conservación del oso andino donde las grandes reservas no son una opción viable. También reconocemos la necesidad de realizar estudios a gran escala utilizando un marco espacial de captura–recaptura y asociar los resultados de la densidad de osos andinos con el uso de recursos para proteger con éxito hábitats con alto valor para los osos andinos.

Key words: capture–recapture, density estimation, pelage color variations, Peru, photographic identification, population density, spectacled bear, *Tremarctos ornatus*

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The continuing loss of biodiversity (functional as well as genetic) remains a major conservation problem of the 21st century. One million animal and plant species are threatened with extinction (IPBES 2019). Especially, large mammals face a high extinction risk, because they require large home ranges, are more prone to hunting pressure, and have low reproductive rates (Cardillo et al. 2005). The population of the only bear species inhabiting South America, the Andean bear (*Tremarctos ornatus*), is projected to decline >30% over the next 30 years and the species is listed as vulnerable on the IUCN Red List of endangered species (Velez–Liendo and Garcia-Rangel 2017).

The Andean bear`s distribution extends across the Andes from Bolivia to Venezuela, overlapping with most of the continent's mammalian fauna (Mares 1992). Considering the overlap with ecoregions, species in need of conservation efforts, as well as overlap with important ecosystem services such as watershed resources (Yerena and García-Rangel 2010), the Andean bear is a suitable umbrella species (Crespon-Gascón and Guerro-Cascado 2019), and its protection will benefit both species diversity and the long-term wellbeing of the countries' economy and the livelihoods of local people (Peyton 1999).

The main threats to Andean bears are habitat loss, habitat fragmentation, poaching, and climate change (Velez–Liendo and Garcia-Rangel 2017). Andean bears are elusive, rarely seen mammals and consequently, they are little-studied and poorly understood in the wild. Andean bears were incorrectly believed to be nocturnal until Paisley and Garshelis (2006) demonstrated their mainly diurnal activities, peaking in the morning and afternoon. Knowledge of Andean bear ecology has improved in recent years, but studies are still lacking to develop successful conservation strategies (Velez–Liendo and Garcia-Rangel 2017).

The estimation of population sizes or densities is crucial to conservation assessments of species and populations (IUCN 2012) because these measurements can inform about extinction risks and are useful to evaluate the effectiveness of conservation management over time (O'Grady et al. 2004). One method to assess population density of bears and other carnivores is through individual identification from photos using capture–recapture analysis (Karanth 1995, Kalle et al. 2011, Swanepoel et al. 2015). Andean bears can be recognized individually by distinctive facial patterns surrounding the eyes and chest (Peyton 1999, Ríos-Uzeda et al. 2007, Zug 2009, van Horn et al. 2014), varying from absent to a complete cover as well as having other color variations (Emmons 1997, Peyton 1999, Ríos-Uzeda et al. 2007, Zug 2009).

Various studies have assessed Andean bear population sizes and density (Ríos-Uzeda et al. 2007, Viteri 2007, Garshelis 2011, Molina et al. 2017, Rodríguez et al. 2020); however, empirical estimates are missing for Peru. Existing estimates from Ecuador and Bolivia vary mostly between 2.9 and 7.5 bears/100 km^2, which is lower than those for the American black bear (*Ursus americanus*), and lower than many estimates for brown bears (*U. arctos;* Miller et al. 1997, Kendall et al. 2008, Gardner et al. 2010).

The accuracy of Andean bear identification from camera traps has not yet been investigated. However, Johansson et al. (2020) showed that individuals of snow leopards

(*Panthera unica*) were consistently misidentified, leading to overestimation of population density through camera-based capture–recapture methods. Although their approach does not reflect common practice for capture–recapture density estimations (see Discussion), this raised concern that, if such misidentifications were applicable across taxa, populations of many endangered species, such as Andean bears, would be even smaller (Johansson et al. 2020).

For successful management guidance and efforts for Andean bear conservation, further knowledge on population density and ecology of Andean bears is important (Peyton 1999, Velez–Liendo and Garcia-Rangel 2017). Thus, the objective of this study is to provide inference on density estimates from a previously unstudied region of Peru, not only through capture–recapture methods, but also based on the occupancy of the area by Andean bear, which is not under the biases as those mentioned by Johansson et al. (2020). Furthermore, we want to report on the behavior of Andean bears from scan observation monitoring of individual bears.

Study area

The data were collected at the site "Copal" (5°46′46.8″S, 77°50′14.8″W), located in the District of Corosha, Region Amazonas, in Northern Peru, within the Tropical Andes Biodiversity hotspot (Fig. 1). People in the local community have known that bears can be observed occasionally there and the first confirmed Andean bear sightings in Copal were reported in 2015. Copal is approximately 400 ha in size and dominated by natural grass and scrublands, with interspersed cloud forest remnants. The grassland vegetation is dominated by *Poaceae* species, but also contain bromeliads as well as a set of fruiting plants from *Ericaceae* and *Rosaceae*, which could be part of Andean bear diet.

The elevation of the area ranges between 2,350 m and 2,600 m above sea level (asl) and the surroundings are dominated by cloud forest and a nearby lake. The area is accessible by a horse trail 6 km from the main road to a nearby settlement (human population approx. 1,000). The zone currently has no official protection; however, the community is requesting its recognition as a private area of conservation.

For this study, we defined the study area as the area observable from one elevated point (2,500 asl). With a viewshed analysis in ArcGIS (Environmental Systems Research Institute, Redlands, California, USA) with terrain data from EOS Landviewer (https://eos.io/) and a 2-km buffer surrounding the observation point, we estimated the visible (i.e., defined as open grassland possible to observe without any barrier) study area to 352 ha. We used a 2-km buffer because Andean bear observations with binoculars further away were considered unlikely.

Methods

Activity and behavioral data collection

We collected scan data on Andean bears from one observation point between 2 November 2016 and 7 March 2017. On overnight excursions, we sampled behavior and activity data between 0600 and 1800 hours. On daily excursions, total sampling duration lasted typically for 4 hours; however, these times varied depending on weather conditions, guide schedule, and time of sunset. To detect bears from the observation point, we scanned the area of Copal with binoculars at a minimum of 10-minute intervals. Once we discovered a bear, we gathered scan data every 5 minutes using binoculars or long-zoom cameras (Nikon D800E/ Nikon D500 [Minato, Tokyo, Japan] with a 150–600-mm f/5.6–6.3 Tamron lens mounted on a tripod). We recorded the activity of each bear, its positions, and its movements until individuals moved out of sight or weather conditions changed. We categorized the activities into feeding, moving, resting, and sniffing–watching. To test differences in frequency between activity categories, we ran a generalized linear mixed-effects model with bear identity and sampling point as random effects and a binomial error structure using the function lmer of the Program R package lme4 (Bates et al. 2015), followed by a Tukey post hoc analysis in R version 3.4.3 (R Core Team 2016). From the scan observation data, we estimated the bears' daily temporal use of the area. We categorized the daily observation time into morning (0600–0959 hr), midday (1000–1359 hr), and afternoon (1400–1800 hr). To test differences in sightings between these times of the day, we used a nonparametric Kruskal–Wallis test followed by a post hoc analysis in R.

Population density estimation

We used 3 different methods to estimate population size, the first based on photographs taken in the vicinity of the view point, producing capture–recapture data, the second based on scan observations, and the third based on capture–recapture data of a golden-morphed individual in relation to sightings of black individuals.

Method 1. Camera capture–recapture density estimation. We photographed bears in Copal with the camera used for individual observations of activity and behavior. Photographs of Andean bears were taken between 22 October 2016 until 9 February 2017, including photographs of Andean bears from Copal, taken by a nature photographer from 22 to 24 October 2016. The main traits used for identification were the facial patterns and chest features. When observers were not sure if the photographed bear was a new individual or already identified, the photographed bear was discarded from analysis, as suggested by Zug (2009). Photos of Andean bears were also discarded when observers disagreed on the identity.

We estimated the Andean bear abundance in R 3.3.1 with the mark–recapture package *Multimark* (McClintock, 2015). Although historical capture–recapture methods used physical capture, marking, and recapturing of animals to estimate population abundances or densities, this R package uses the "noninvasive" capture–recapture sampling technique (McClintock 2015). Noninvasive, meaning natural marks, can include pelt or skin pattern (McClintock 2015), such as the facial markings of Andean bears in this study. We performed a Bayesian inference model based on closed populations and the data consisted of single-mark type (i.e., only one trait is used for identification). With a collection of observation histories, we could calculate population density.

We used home range estimates of Andean bears by Castellanos (2011), acquired through telemetry data (Table 1), to calculate density. Here we used annual estimates by Castellanos (2011) and chose the k-NNCH model, which was considered the best home range estimation by Castellanos (2011). Males and females have different home ranges, so Andean bear density estimations are also dependent on supposed gender ratio in small study areas. Male Andean bears have almost 4 times larger home ranges than females (Castellanos 2011); so, Copal is likely part of the home range of more individual males, whereas females are expected to spend a longer time in the area per individual. Therefore, we used the annual home-range estimations with a 4:1 male:female ratio by Castellanos (2011; see Table 1), to estimate the average home-range size of Andean bears in Copal, equating to 50.22 km^2. Based on this home range, we used a 4.00-km buffer (calculated from $(50.22/\pi)^{0.5}$) around our study area. This is similar to the 4.40-km mean maximum distance moved (MMDM) between camera traps reported in Molina et al. (2017).

Method 2. Local population estimated based on the proportion of occupancy. Our second density estimation was based on an occupancy model, in which bear identity was unknown (Sollmann 2018). Garshelis (2011) illustrated how one could crudely calculate a minimum density of bears in an area using telemetry data. However, instead of telemetry data, here, we used the time bears were visually observed in the area. This means, based on our observations, we calculated the proportion of time bears were observed in Copal to indicate the population density. Forested areas were excluded from the study area for the density estimate by using vegetation data from 2016 from EOS Landviewer in ArcGIS. This reduced the total area in which bears could be observed to 2.10 km^2. We sampled a small area; therefore, Method 2, which was calculated from the proportion of the occupancy, only provides an inference of the actual density. However, unlike our other density estimates, the occupancy model does not use home range estimates or individual identifications of bears and therefore complements our other estimates.

Members of the Nongovernmental Organisation Yunkawasi, which consists of researchers and conservationists, have visited Copal since September 2015 and have recorded the daily absence and presence of bears since then. However, they did not record the length of observations. To allow us to use this data for density estimations, we used the average daily abundance of Andean bears in Copal (for details see Data set C, Table 2) for the previously recorded sightings. We used these data because they provided better insight into the abundance patterns of bears in Copal since 2015. For the density estimation, we only used observations between the months of October to February because we lacked the number of sampling occasions from the rest of the year. Occupancy data from these 5 months comprised 81% of the total amount of data collected.

Method 3. Density estimations based on a golden-brown pelaged Andean bear. Two color morphs of the Andean bear had been observed prior to this article, black and red-brown (Peyton 1999). An Andean bear with golden-brown fur (Fig. 2) was recorded for the first time on 25 August 2016 in Copal. Since then, a bear with golden fur has been seen additionally 9 times, with its last official record on 25 April 2017. The photographs show that the individual has a pink nose with facial patterns typical of Andean bears (Fig. 2). We conducted a literature research and concluded no other known recordings of Andean bears with a golden coat (Peyton 1999; I. Goldstein, Andean Bear Conservation Alliance, personal communication).

The golden bear had a unique pelage and was immediately recognizable, so it is possible to obtain an estimate of Andean bears in Copal based on the frequency of sightings of golden bears compared with other individuals. We used this information in a capture–recapture model (Otis et al. 1978, Petersen 1896) to calculate the population density, and we used confidence intervals based on the Poisson frequency distribution. Like Method 2, this estimate was crude because different bear individuals probably spend different amounts of time in Copal, depending on gender, home range, and the presence of other bears. Here, data collection was performed over several years, so we used Castellanos' annual home-range estimation for density estimates.

Recalculating density estimations by Molina et al. (2017)

In order to accurately compare studies making density estimates by capture–recapture, one must use similar ecological features, such as home range, in order to draw conclusions on similarities or differences in their findings (Sollman 2018). Molina et al. (2017) performed a study using a study area of approximately 120.59 km^2 (our calculation based on available data from Molina et al. 2017) and estimated Andean bear density to 7.45/100 km^2 in their study area in Ecuador. However, although Molina et al. (2017) claimed to use their MMDM of 4.40 km as a buffer, they actually used a 10-km buffer. To make estimates from Molina et al. (2017) more comparable with the results of our study, we recalculated their density estimate based on their MMDM of 4.40 km. This buffer was similar to our buffer size in Method 1 and Method 3 (4.0 km).

Results

Activity and behavior

Andean bears were observed in the grasslands in Copal on 321 scans (i.e., 5-min time intervals). They were observed throughout the day, but were recorded more frequently during the morning (37.59%, SD = 57.50%) and the afternoon (37.69%, SD = 48.58%), compared with midday (21.70%, SD = 41.69%; Kruskal–Wallis Test, post hoc analysis, $\chi^2 = 24.453$, df 2, $P < 0.001$; Fig. 3). Andean bears were primarily feeding (72.9%, SD = 44.5%) and were otherwise moving (12.7%, SD = 33.3%); 0.30% of the scans bears were doing other activities, 13.3% of the scans were undefined, and bears were never recorded resting. All activities differ significantly from each other (Tukey post hoc test: $P < 0.001$). Food choice was rarely possible to determine, but in 3 events Andean bears were recorded feeding on *Puya* sp. and on 1 occasion on *Poaceae*–*Cyperaceae* sp.

Andean bear density: Method 1

Between 22 October 2016 and 10 February 2017, bears were observed 29 times and, if feasible, photographed. This resulted in 7 events where bears could be successfully identified based on facial markings, with identification of 5 bear individuals and 2 recaptures (Data set A, Table 2). We estimated that 8.34 (95% CI = 5.00–20.00) individual bears used the effective sampling area (80.32 km^2, Table 1). Using the yearly home-range estimates and a 4:1 gender ratio, density was estimated to be 10.38 bears/100 km^2 (95% CI = 6.23–24.90 bears/100 km^2).

Andean bear density: Method 2

During the period of October until February in 2015–2016 and 2016–2017, we collected data on 46 occasions (presence–absence Data set B, Table 2). Bears were seen on 24 of these occasions (52.2%) with 52 bears observed in total (average per visit = 1.11, SD = 1.26). At most, 4 individual bears were seen on the same day (this was confirmed to be 4 different individuals, because 3 black bears were seen simultaneously and the golden bear was seen later). Scan observations, meaning recording of the time observed and the length of the observation, were collected on 35 bears (Data set C, Table 2). On average, an individual bear was visible in Copal 33.0% of the observation time (with an average of 101 min/bear, SD = 97 min/bear). We estimated the number of bears (average N bears per occasion × occupancy × area) in Copal was 17.39 bears/100 km^2 (95% CI = 11.67–23.10 bears/100 km^2, based on 33.0% occupancy; Table 1).

Andean bear density: Method 3

Nine observations of a bear with golden pelage were made among the 64 observations of bears between 29 September 2015 until 1 April 2017 (Data set D, Table

2). This allowed us to estimate the number of bear individuals visiting Copal to 7.11 bears (95% CI = 5.02–9.21 bears). Using the k-NNCH telemetry data estimates from Castellanos (2011) for home range estimations, population density was calculated to 8.85 bears/100 km^2 (95% CI = 6.25–11.46 bears/100 km^2; Table 1).

Andean bear density: Molina et al. (2017) recalculation based on MMDM

To make our results more comparable with those of Molina et al. (2017), we recalculated the density estimates from Molina et al. (2017) using a buffer based on the MMDM of Andean bears from their studies, instead of a 10-km buffer. Molina et al. (2017) used a 824.04-km^2 effective trapping area, including the buffer. From this, we calculated the radius of the study area ($(824.04/\pi)^{0.5}$-10) and the area of the effective trapping area based on the 4.40-km MMDM (See table 1 in Molina et al. 2017). The effective sampling area was 352.78 km^2, resulting in an Andean bear density of 11.49 bears/100 km^2 (95% CI = 4.18–18.80/100 km^2).

Discussion

In this study, we present the first estimates of Andean bear density from a study area in Peru based on empirical data, calculated by 3 different methods, and indicating a density between 8.85 and 17.39 bears/100 km^2 . We also report the first record of a golden-brown pelage in Andean bears. The bear appeared to not be albino, but the coloration may be due to a recessive gene expression because of a lack of heterozygosity (Lairke et al. 1996). The cause of this color variation must be studied further to better understand whether it is an indication of genetic challenges facing Andean bears in Peru. Furthermore, we found Andean bears to have a bimodal distribution of activity, supporting the current view of Andean bear activity patterns (Paisley and Garshelis 2006, Zapata-Ríos and Branch 2016).

We suggest that the estimate of Method 1, 10.38 bears/100 km^2, was the most reliable because it provided better closure of the population (compared with Method 2) and was based on differences between individual bears (compared with Method 3). We also suggest that a more correct Andean bear density from Ecuador using data by Molina et al. (2017) should be 11.49 bears/100 km^2, based on MMDM, instead of a 10-km buffer. Method 2 and Method 3, although less reliable, also supported this density estimate. All density estimates from our study, including the recalculation of Molina et al. (2017), were higher than estimates from previous studies (Ríos-Uzeda et al. 2007, Viteri 2007, Garshelis 2011, Molina et al. 2017, Rodríguez et al. 2020). However, we believe that it should be further investigated whether these higher estimates are representative only for Andean bear hotspots or also on a larger scale.

Although the estimate from our study may seem high, compared with the results of previous studies on Andean bear density (2.9–7.5 bears/100 km^2, see Ríos-Uzeda et al. 2007, Viteri 2007, Molina et al. 2017, Rodriguez et al. 2020), we suggest that data from some of the previous studies demonstrated that Andean bears live locally in higher densities. For example, Rodriguez et al. (2020) found that Andean bear density was 2.9 individuals/100 km^2 across 9 municipalities in a large study in Colombia. However, they found 27 different Andean bear individuals (47% of all detections) in only one sampling area with a similar size to Copal. Garshelis (2011) showed that Andean bear density from the same area as Ríos-Uzeda et al. (2007) was ≥11 bears/100 km^2, compared with 4.4–6 bears estimated in the original study. Similarly to the present study, Zug (2009) found 5 different individual bears in a small study area, but with only a single independent recapture during 4 months of sampling.

Molina et al. (2017) used a 10-km buffer, despite a 4.40-km MMDR (see table 1 in Molina et al. 2017), which deviated from the method description and is one reason that we calculated a new estimate, based on the data from their study. However, 10 km can be justified to use as a buffer for Andean bears. Rodriguez et al. (2020) found that some individuals moved >20 km, which further adds uncertainty to the density estimations of previous and present camera-trap studies to study Andean bear density. Furthermore, Johansson et al. (2020) empirically tested the reliability of density estimations based on camera-trap studies in snow leopards, concluding that observers' misidentifications consistently led to overestimations. This raised the concern that, if applicable across taxa, populations of many threatened species (such as the Andean bear) would be smaller than previously believed, and would, in the case for Andean bears, apply to a majority of the studies on Andean bear population density and abundance because capture–recapture methods are commonly used. However, Johansson et al. (2020) only used opinions of isolated observers to test their hypothesis, which is often in contrast to capture–recapture protocols, where several observers identify individuals (present study; Zug 2009, Molina et al. 2017) and where splitting errors exemplified in Johansson et al. (2020) are excluded. Moreover, different taxa are not equally identifiable because this is the fundamental reason that only a handful of species are targeted for noninvasive capture–recapture studies. Nonetheless, we recognize that there are limitations to the capture–recapture methodology, which calls for comprehensive studies and well-developed frameworks.

The conservation of Andean bears can be difficult because they live at large spatial scales and have high metabolic needs (Dierenfeld 1988, Castellanos 2011, Rodriguez et al. 2020). With a larger human population and consequently land-use intensification in the Andes, an increase in human–Andean bears conflicts has been observed (Zukowski and Ormsby 2016). Therefore, local areas like Copal, that are intensively used by Andean bears for feeding, could be of great importance for successful Andean bear conservation. Focusing conservation efforts on small reserves, where larger protected areas are not possible, could be an opportunity for conservation; such strategy may also decrease human–bear conflicts because food resources are a major cause for tension (Zukowski and Ormsby 2016). Smaller reserves may also be easier to establish. Indeed, a majority of Peruvian protected areas are of a small size (Fajardo et al. 2014).

Although the main results from Rodriguez et al. (2020) indicate the lowest density of all previous studies on Andean bear density (2.9 bears/100 km^2), adding spatial differences into consideration would likely have shown Andean bear density to be variable and locally to exceed the densities found in this study. Therefore, we believe consideration of scale is of great importance for future efforts in both conservation and research of Andean bears. Large-scale studies, such as Rodriguez et al. (2020), are generally considered more reliable; however, in order to understand bear distribution patterns across landscapes and habitats, emphasis on a smaller scale can be of help. This calls for a future focus on Andean bear density within a spatial capture–recapture framework (Royle et al. 2014) in large studies.

Andean bears were primarily seen feeding in the area (86.6% of the time); therefore, we believe food availability was driving bears to visit the Copal. However, bears were only seen feeding on *Puya* sp. or *Poaceae–Cyperaceae* sp., which grow all year round (Peyton 1984). Thus, it may not be the seasonal abundance of food in Copal, but rather the lack of food availability in the surrounding landscape, that drives Andean bears to visit the area. Results from Castellanos (2011) indicate that Andean bears use different parts of their range depending on the season. A more complete understanding is needed of how Andean bears use different resources temporally, and to connect that to their seasonal movements and densities. With this knowledge we can better understand how to efficiently protect Andean bear habitat.

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Table 1. Andean bear (*Tremarctos ornatus*) density estimation (individuals/100 km^2) at the study site Copal in northern Peru, calculated by 3 different methods from 2015 to 2017 (see Table 2).

Method	Home range variable[a]	Home range estimates (km^2)	No. of Andean bears[b]	Effective sampling area in km^2	Bear density/100 km^2	95% CI low	95% high
1	Yearly (k-NNCH)	50.22	8.34	80.32	10.38	6.23	24.90
2	NA	NA	0.37	2.10	17.39	11.67	23.10
3	Yearly (k-NNCH)	50.22	7.11	80.32	8.85	6.25	11.46

[a] The home range estimates are based on a 4:1 gender ratio from yearly home-range estimations by Castellanos (2011). Home range values were not applicable for Method 2.

[b] The no. of Andean bears is the estimate of Andean bears with Copal included in their home range for Methods 1 and 3, while for Method 2 it is the no. of bears present in Copal at any point of time.

Table 2. Overview of the different data sets and methods used to estimate density of Andean bears (*Tremarctos ornatus;* individuals/100 km^2) at the study site Copal in northern Peru, and time period during which data were collected.

			Sampling period				
Data set	**Method**	**Data type**	**Month**	**Year**	***N* Sampling**	***N* bears sightings**	**Recaptures**
A	Method 1	Capture–recapture	22 Oct–12 Feb	2016–2017	35	7	2
B	Method 2	Presence–absence	1 Oct–28 Feb	2015–2016, 2016–2017	46	55	NA
C	Method 2	Occupancy	2 Nov–24 Apr	2016–2017	41	30	NA
D	Method 3	Capture–recapture	29 Sep 15–24 Apr 17	2015, 2016, 2017	56	64	9

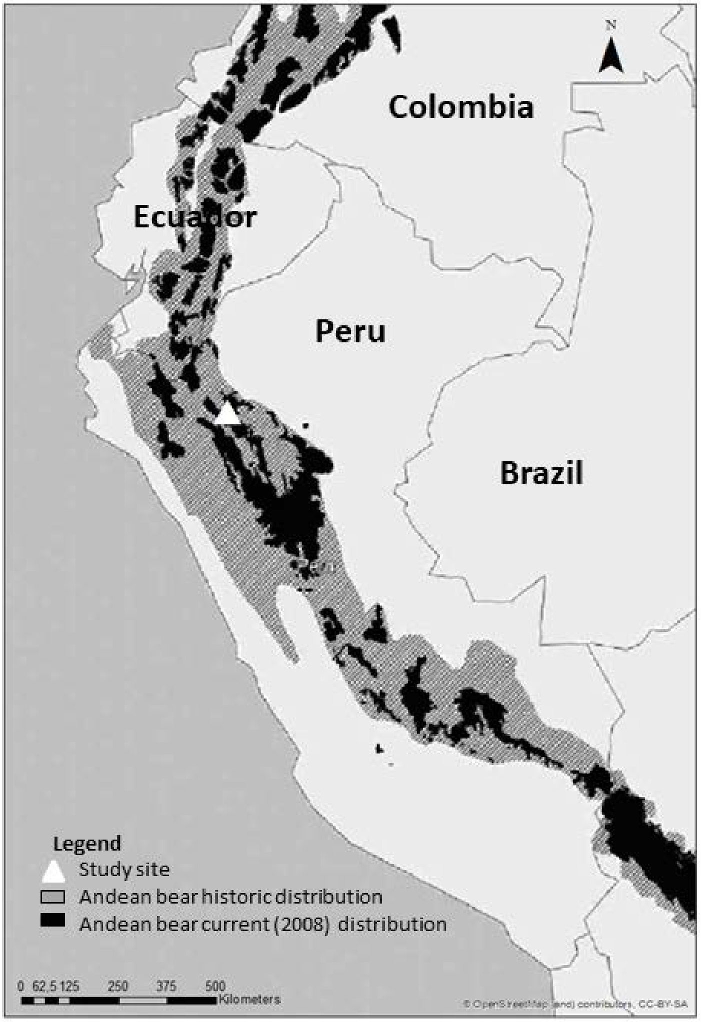
N
Colombia
Ecuador
Peru
Brazil
Legend
Study site
Andean bear historic distribution
Andean bear current (2008) distribution
0 62,5 125 250 375 500
Kilometers

Fig. 1. Location of the study site in Copal, Northern Peru, where 3 methods were used from 2015 to 2017 to calculate Andean bear density(see Table 2), and the Andean bear's (*Tremarctos ornatus*), as well as the historic and current (2008) distribution (modified from García-Rangel 2012).

Fig. 2. The golden-pelaged Andean bear (*Tremarctos ornatus*) in the study area of Copal, Northern Peru (credits: M. Tweddle).

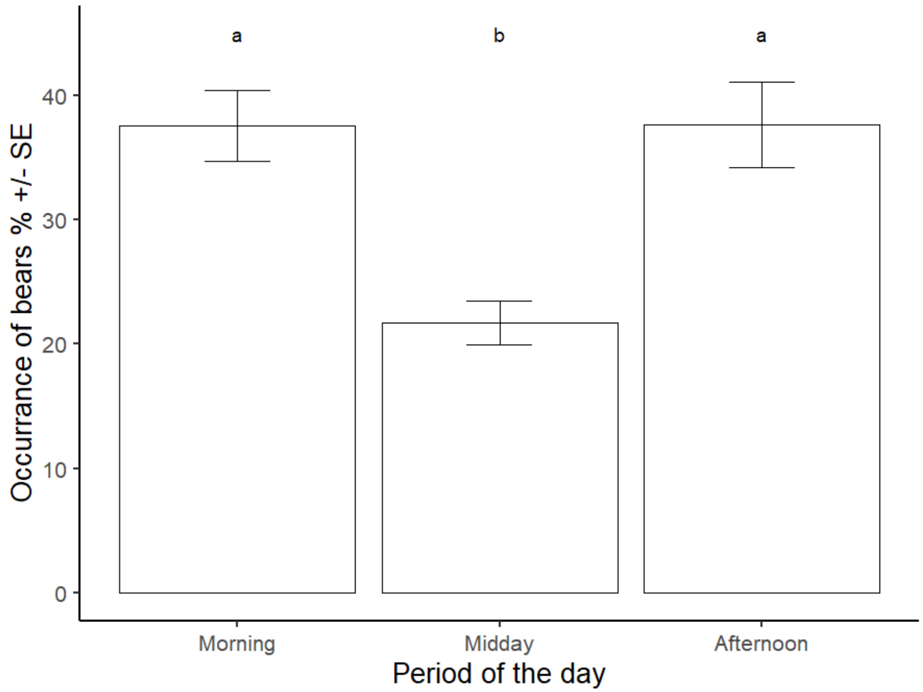

Fig. 3. Average occurrence (±SE) of Andean bears between November 2016 and April 2017 (*Tremarctos ornatus*) at the study site Copal in northern Peru, during morning (0600–1000 hr), midday (1000–1400 hr), and afternoon (1400–1800 hr). Activity in the grassland during midday was significantly lower compared with morning and afternoon (*P* < 0.001) indicated by different letters.