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Selection of Trees Marked by Rubbing by Andean Bears in the Peruvian Dry Forest

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Preface

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Abstract

The Andean bear (*Tremarctus ornatus*) is one of the least known species of Ursidae. One area about which very little is known is the bear's marking behavior. This is a key aspect of bear ecology and marks can give information on the behavior and relative abundance of the species in an area. Mammalian selection of marking sites is associated with location, often in areas frequently used by conspecifics, and the physical characteristics of the tree or substrate used for marking. In this study I tested the hypothesis that Andean bears in the Peruvian dry forest leave more rub marks on trees close to water and on certain species based on the size and characteristics of the tree. Analysis of 117 mark locations, 94 rub trees and 243 available trees within a 5-m radius of rub trees, hereafter called unmarked trees showed that the bears preferred to rub trees with a smaller height and closer to water holes. Water is rare in the dry forest and waterholes act as a central point for bear activity. The highest selection ratio for rub trees was found for chilco (*Baccharis sp.*), chaquiroz (*Pithecellobium excellsum*), vichayo (*Beautempsia avicenniifolia*), and vichayo falso (*Capparicordis crotonoides*). These species may have been chosen because of the resin and sap properties of the bark and the trees' aroma, which could help the persistence and detection of bear signal by conspecifics. This study presents the first insight into how bears of the Peruvian dry forest rub trees for communication and could assist in future study and conservation of this species.

Introduction

The Andean bear (*Tremarctos ornatus*) is vulnerable to extinction throughout its range in the Andes Mountains of South America (Goldstein et al. 2008b). The Andean bears distribution only comprises 3.2% of the land area of South America, but contains 76% of the continent's mammalian species (Peyton 1999). This and the bear's large spatial requirements makes it an umbrella species for the conservation and management of Andean habitats (Castellanos 2003). Despite their charisma and status as an endangered species, the Andean bear still remains one of the least known members of the family Ursidae (Garcia-Rangel 2012). One area in which very little is known is the bear's marking behavior. There have been no published studies on the marking behavior of Andean bears in dry forest. Investigating the marking behavior of bears helps us to better understand the breeding behavior, social organization and the relative abundance of the species (Steinmetz & Garshelis 2007), through the use of hair found at rub trees (Henderson et al. 2015; Stetz et al. 2014).

Scent marks are deposited by mammals as a means of intraspecific communication and scent marks are thought to function in advertising territory ownership, social dominance, status, and to attract mates (Ralls 1971; Thonhauser et al. 2013). Chemical communication helps to prime sexual motivation in giant pandas (*Ailuropoda melanoleuca*) (Swaigood et al. 2004) and other mammal species (Johnston et al. 1999), prior to sexual encounters. For nonterritorial large mammals, such as bears, indirect communication through chemical signaling is a necessity (Clapham et al. 2012) and helps individuals gain access to mates, control a resource, or exert dominance (Brennan & Keverne 1997). Marking behavior of bears has been described as clawing, biting, rubbing, and urinating on trees or other substrates. This behavior is thought to

vary by season, age, and sex of bear (Clapham et al. 2012). Marking has been observed in female brown bears (*Ursus arctos*) (Clapham et al. 2012), but is thought to be primarily a male behavior in all bear species (Burst & Pelton 1983; Clapham et al. 2013; Taylor et al. 2015). Studies on American black bears (*Ursus americanus*) and brown bears have shown a peak in marking just before or during the mating and molting seasons (Burst & Pelton 1983; Clapham et al. 2012; Green et al. 2003; Rogers 1977).

There are many hypotheses about why bears carry out marking behavior, but none have been tested conclusively (Burst & Pelton 1983). Some researchers have speculated that marking is a form of body care (Meyer-Holzapfel 1968), whereas others believe it serves the same social function as canid urinary posts, acting as ‘information places’ (Burst & Pelton 1983; Green et al. 2003; Stirling & Derocher 1990). Murie (1981) believed this behavior to be a form of massage, after he observed bears rubbing boulders, downed tower poles, and even the ground in the absence of trees. Others came to the conclusion that rubbing and scratching trees was a response to insect bites, a form of stretching, or a way of abrading their claws (Meyer-Holzapfel 1968). American black bears in Quebec rub fir trees (*Abies amabilis*) to cover themselves in the sap, which is believed to act as a repellent against black flies (*Simulium* spp) (Engel 2002). Brown bears in Greece rub on power poles covered in a creosote preservative. This is thought to be a way of alleviating ectoparasites (Karamanlidis et al. 2010). Bromlei (1965) also described rubbing of brown bears in the early spring and summer as a response to biting insects.

Today there is more evidence to support marking behavior as a means of chemical and social communication in bear species (Clapham et al. 2012; Clapham et al. 2013; Nie et al. 2012; Novikov et al. 1969; Tattonia et al. 2015; Taylor et al. 2015). Clapham et al. (2012) found that marking behavior in brown bears serves to communicate dominance between males. After observing dominant male brown bears marking during the breeding season, Gilbert (1999), concluded that marking trees help to communicate dominance and reduce conflict in areas with females, food, and scarce resources. The same trees can be marked for years (Burst & Pelton 1983; Goldstein et al. 2008a), and often by generation of bears over different breeding seasons (Schaller et al. 1985). These ‘traditionally’ marked trees can be visited by many bears, which emphasizes the link between marking behavior and intraspecific communication (Clapham et al. 2012). Mark-remark trees, as they are referred to, are very common along Andean bear trails (Goldstein et al. 2008a).

As stated above, marked trees are thought to serve a function in the chemical communication of ursids (Clapham et al. 2013; Green et al. 2003; Nie et al. 2012). Biting, clawing, and rubbing trees allows brown bears to deposit their scent through the sebaceous, apocrine, pedal, and salivary glands (Clapham et al. 2013). Urinating on trees and anal gland secretions are also used by bears as signals (Swaigood et al. 1999; White et al. 2003). In the giant panda, this is done with a waxy substance that is produced in the anal gland (Nie et al. 2012). The combination of chemical and visual marking systems can help advertise a brown bear’s presence to conspecifics (Green et al. 2003). It is important for pandas to deposit the scent marks in locations most likely to be detected, as chemical marks are energetically costly and time consuming to deposit (Gosling & Roberts 2001; Nie et al. 2012).

It has been suggested that Andean bears communicate by leaving scent from scent glands on their skin in scratch marks on trees (Goldstein 1990; Goldstein 2002; Peyton 1980; Peyton 1984; Ríos-Uzeda et al. 2006). Using trees to mark on has advantages, because the height of the mark and the trees' sap help retain and disperse the bears' scent (Burst & Pelton 1983). Mark trees are often located on the portion of the trails that is visible to other bears. This indicates that bears consider the visibility and location of the substrate when they select trees to mark on (Green et al. 2003). Andean bears demonstrate the importance of visibility by marking on the sides of trees facing trail entrances near concentrated food sources or along ridge lines (Peyton 1994). Clapham et al. (2013) found that location was the main criteria for selection of mark trees by brown bears. This was followed by characteristics of the tree that make it unique in the landscapes, such as size, aromas, and the ability of the sap to hold the bear scent longer (Clapham et al. 2013). Similarly, cervids select rub trees based on the trees' physical characteristics (Johansson & Liberg 2000; Massei et al. 1999) and aromatic properties (Kile & Marchinton 1977). Pedal gland marking by felids is often followed by scratching the earth. This is thought to attract a conspecifics' attention through the smell of freshly disturbed earth (Eisenberg & Kleiman 1972). The marking behavior of the Asiatic elephant (*Elephas maximus* L.) not only involves the deposition of scent, but also making an area conspicuous through disturbance of trees that release odors (Eisenberg & Lockhart 1972). In a study carried out in Apolobamba National Park, Bolivia, Andean bears were found to be attracted to aromas, in particular the smell of perfume (Chanel No 5) (Wallace 2013). The giant panda selects trees to mark based on the bark's roughness, presence of moss, tree diameter, and distance to a bear trail. These characteristics are thought to aid in bear signal persistence and detection (Nie et al. 2012). Green, et al. (2003) found that diameter of the tree was the main criteria for brown bear's selection of trees. Seryodkin et al. (2014) believe that brown bears prefer to mark trees with thick diameters.

Based on literature on ursid marking behavior, we hypothesized that Andean bears of the Peruvian dry forest select trees to mark that are (1) located closer to water holes, (2) larger in size, and (3) contain characteristics that could aid in intraspecific communication. Water is a limited resource in the dry forest and water holes act as central places for Andean bear activity. Marking on trees closer to water holes could increase the chances of signal detection by conspecifics. Marking on trees that are larger in size could improve the visibility of the mark, and elevated marks could help disperse the bears' scent. Characteristics of the tree that make it unique, such as bark texture or aromatic properties could help signal persistence or detection. The dry forest of northern Peru is a threatened habitat and the loss or endangerment of these tree species and water holes could disturb the bears' communication system. One of the biggest threats to the survival of Andean bears is a lack of knowledge about the bears' distribution and status (Goldstein et al. 2008b; Peyton 1999; Rodríguez-Clark & Sánchez-Mercado 2006). Collecting information on preferred habitat features and behavioral aspects of the Andean bear is therefore essential for the conservation and management of this species.

Study Area

The dry forest of northern Peru forms a narrow strip flanking a 100-km stretch of the western Andes foothills, bordered to the west by coastal desert (Figure 1). The area is threatened in the lowlands by free-ranging cattle, large-scale sugar cane and rice plantations, and in the uplands from subsistence maize farming. There are also threats from extractive mining development (Appleton et al. 2009). Efforts to conserve dry forests have been hampered by the lack of knowledge about the floristic composition, structure, and ecology of this ecosystem (Edinburgh 2012). The climate is extreme, with temperatures in the lows averaging 18 °C and the highs 38 °C, and an annual mean rainfall c. 200 mm (range c. 50 mm – c. 1000 mm) (Linares-Palomino & Ponce-Alvarez 2009). During El Niño storms, a humid tropical climate with rainfall exceeding 1000 mm a year replaces the arid tropical climate (Appleton et al. 2009).

This study was conducted with the Spectacled Bear Conservation Society (SBC). SBC has been conducting research on Andean bears of the region since 2008 and has identified over 35 individual bears and cubs (Figure 2) (SBC Peru 2011). The field work was conducted at six different water hole locations spread out over approximately 100 km² of western Andes foothills (Figure 3). The mountainous terrain of the site consists of three adjoining peaks Cerro de Venado, Calaboso, Motopillo, a flank called Cerro la Traposa, and another peak to east, Cerro la Careza. The mountains have steep slopes that sharply descend 150-500 m/km into dry stream beds and valleys filled with boulders. Small springs supply water year round to a small number of water holes. These water holes were generally located at elevations ranging from 441 to 1005 masl. The water hole, ‘Debujos’ was located at 441 m on a southern flank of Cerro Motupillo. The water hole ‘Sogas’ was located at 1005 m on the mountain peak Motupillo. Mayascon was found at 578 m on Cerro la Traposa. ‘Calaboso’ was located at 578 m on Cerro la Calaboso. The permanent and temporary water holes found at Agua del Oso were located at 935 m and 958 m, between Cerro de Venado, Calaboso and Motopillo, but closer to Cerro de Venado. These water holes act as central points where Andean bear travel to and meet (Appleton 2013).

The vegetation plain of the site is typical of Pacific Tropical Desert, Arid Tropical Desert, and Super-Arid Pre-Mountainous Desert. Vegetation associated with this region includes algarrobo (*Prosopis spp.*), charpa (*Leucaena trichodes*), chaquiroz (*Pithecellobium excellsum*), chimulala (*Acnistus arborescens*), faique (*Acacia macracantha*), frijolillo (*Capparis flexuosa*), higueron (*Ficus padifolia kunth*), hualtaco (*Loxopterigium huasango*), overo (*Cordia lutea*), pai pai (*Caesalpinia glabrata*), palo blanco (*Celtis triflora*), palo santo (*Bursera graveolens*), palo verde (*Cercidium praecox*), papaya silvestre (*Carica parviflora*), papelillo (*Bougainvillea pachyphylla*), pasallo (*Eriotheca ruizii*), sapote (*Colicodendrum scabridum*), tunga (*Croton sp.*), vichayo (*Beautempsia avicenniifolia*), vichayo falso (*Capparicordis crotonoides*), waylulo (*Erythrina smithiana*), tupla (*Acnistus arborescens*), chilco (*Baccharis sp.*), lucraco (*Waltheria ovata*), cautivo (*Wedelia latifolia*), firn (*Trismeria trifoliata*), and five species of cactus (*Cactaceae*). Above 600 m, forests of pasallo (*Eriotheca ruizii*) and palo santo (*Bursera graveolens*) dominate. Lower elevations are dominated by overo and sapote (Linares-Palomino & Ponce-Alvarez 2009).

Other mammals that can be found in the study area include, puma (*Puma concolor*), northern tamandua (*Tamandua mexicana*), striped hog-nosed skunk (*Conepatus semistriatus*), collared peccary (*Pecari tajacu*), ocolot (*Leopardus pardalis*), common opossum (*Didelphis marsupialis*), Sechuran fox (*Lycalopex sechurae*), tayra (*Eira Barbara*), white-tailed deer (*Odocoileus virginianus*), and colocolo (*Leopardus colocolo*) (Pacheco et al. 2009).

Study Species

Like other bears, Andean bears are generally solitary (Servheen et al. 1999). Andean bears are active during the day (Paisly & Garshelis 2006). In the Peruvian dry forest, when the heat is most extreme in the middle of the day, bears retreat to higher elevations, where they drink and bath at water holes and build daybeds to rest (Appleton et al. 2009). Andean bears occupy a variety of ecosystems throughout their range, from dry areas in the coastal range of Peru to humid cloud forest and paramo (high elevation grassland) (Kattan et al. 2004), where they are most frequently found (Garcia-Rangel 2012). Habitat selection by Andean bear is thought to be mostly related to the elevation of the habitat and potential food sources located there (Peyton 1980). Andean bears follow seasonal patterns of food resources (Kattan et al. 2004). This forces the bears to use a combination of habitat types to secure access to different food sources (Garcia-Rangel 2012; Kattan et al. 2004; Ríos-Uzeda et al. 2006).

Fruits make up the most important part of the bears' energy source (Cavelier et al. 2010). Peyton (1980) identified 31 species of fruiting tree that represented 28.7% of the bears' diet. During the summer months in the Peruvian dry forest (December – March), bears feed almost exclusively on sapote fruit. After March they primarily feed on the core wood of pasallo and periodically feed on land snails, honey bee hives, overo, and vichayo fruit, and cactus on the upper slopes of the mountain (Appleton et al. 2009). In cloud forest habitat their diet also consists of vegetable matter, such as meristematic tissues of palms, bromeliads, and bamboos (Goldstein 2004). Andean bear occasionally eat meat and studies on scat samples have confirmed the presence of livestock, rodents, deer, tapirs (*Tapirus pinchaque*), and birds in their diet (Troya et al. 2004)

Andean bears are a facultative seasonal breeder and mate throughout the year in the wild. In the cloud forests of Peru, a peak in the breeding behavior has been observed between March and October during the fruiting season (Peyton 1980; Spady et al. 2007). Bears of the Peruvian dry forest also time breeding early in the sapote fruiting season between December and January (Appleton et al. 2009)

Methods

The method to collect data was one that could be easily used with limited materials and training. With the location of this study and the little time that was available, it was important to collect as much data from the marks as possible within one month.

In comparison to other surveying techniques for large carnivores, surveys on bear marking behavior can be conducted without the use of expensive equipment and with minimal training (Steinmetz & Garshelis 2007). This is particularly useful throughout the Andes where financial constraints are an obstacle for Andean bear conservation. The materials used in this survey include a field notebook, tape measure (cm), 100-m field tape measure, digital camera (Canon PowerShot ELPH 300HS), handheld (Global Positioning System (GPS) device (Garmin GPSMAP 62 series), field boots, hat, and protective clothing for the sun and dense shrub.

The open terrain of the dry forest provides visibility and allows for easy detection of bear sign year round. The arid environment also concentrates bear activity around infrequent water holes. The locations of these water holes and bear trails are well known by SBC (Appleton et al. 2009). With this information, we mapped out trails and six waterholes to visit during field trips. Both water holes with a high amount of bear activity and little bear activity were surveyed.

The GPS location of a water hole was taken to establish the starting point for the bear trail transects. The name of the water hole was given as the site name. A quick survey of the surrounding area was carried out to establish the number of bear trails leading to and from the water hole. The bear trails were then assigned transect numbers 1-5, depending on number found at each the site. Using a 100-m long measuring tape we tracked the distance travelled from the water hole along each transect. The minimum distance for each transect was 150 m. When marks were found beyond 150 m, the bear trail was traveled until no more were detected (at least 50 m after the last mark). The longest transect stretched for 2 km.

When a marked tree was encountered along a transect, it was assigned a number based on the order in which it was found and the transect it was on. The GPS location was then taken at an accuracy of 5 m. This high GPS accuracy was possible due to the lack of tree canopy cover in the dry forest. An experienced field staff then identified the common name of the species of tree or plant that had been marked. Three photos were taken of each marked plant in case the field team was not able to identify it. Pictures were taken of the leaves, and any visible fruit to aid in identification. Sixteen different categories of information were compiled, including transect and track number, distance of marked trees (m) to water hole, distance of unmarked trees within 5 m of the marked tree, species of tree, stem circumference (cm), height of tree (m), tree canopy width (m), maximum height of rub (cm), the presence of rub marks, bite marks, scratch marks, hair, presence of sap, the estimated age of mark, and presence of pede-marks. Pede-marks occur when bears deliberately twist or shuffle their feet into the ground to deposit their scent (Taylor et al. 2015). The circumference at breast height of marked and unmarked trees was converted to diameter at breast height (DBH). When branches were found with multiple stems or trunks, the overall DBH was the square root of the sum of each diameter squared. Marks were defined as rub marks, scratch marks, bites marks, or pede marks. Contrasting ‘presence’ (i.e. marks that are present on trees) with ‘absence’ (i.e. on nearby unmarked trees) is a common technique to

identify patterns in ecological systems (Manel et al. 2001). The data collection was carried out over the course of eight days between December 2014 and January 2015.

The field staff helped to distinguish the difference between pede marks used for marking and prints made by animals walking along the trail. Some scratch and rub marks were difficult to distinguish from the trees bark or branches that had been broken by other animals. The field team were key for making this distinction. Rub marks were identified by the presence of bear hair, scratch marks, discoloration of the bark due to bear rubbing, bite marks, and the size and manner in which branches of the tree/ shrub were broken or bent. When marks were found within 1 m of each other or on the same substrate, they were considered to be one mark.

To compare marked trees with the surrounding substrate, all species of trees within a 5-m radius of each mark were recorded for measurements. This method was used by Clapham et al. (2013) when working with brown bear marking behavior in Canada. We identified the species of trees, and assigned them a number indicating the transect and mark they were closest to. Photos were taken and sent to Reynaldo Linares-Palomino, a leading botanist of dry forest vegetation, to confirm identification. To allow for comparison with marked trees, the circumference of the tree at breast height was measured along with the maximum height and canopy cover of the tree. The distance the tree stood from the mark site was also measured.

Statistical analysis

Mixed effects logistic regression models were applied to the marking tree data to assess whether the site, height, canopy width, or DBH of trees differed between used and available trees. We used a generalized linear mixed model (GLMM) fit by a maximum likelihood estimator with a Laplace approximation. To make the data consistent and distinguish between different marking behaviors, we only included rub marks in our analysis, and excluded the mark sites with only sunken footprints ($N = 16$), bite marks ($N = 8$), or scratch marks ($N = 26$). For statistical analysis, the 240 remaining trees were assigned a 1 or 0 depending on whether or not the tree was marked. This served as the binomial response variable in my model. The explanatory variables used in the analysis were the fixed factors of tree height, tree canopy width, DBH and site (Table 2).

To identify if marking trees occurred closer to water holes than random, we paired the distance from each marked tree to the nearest water hole with a random distance. The maximum random distance was restricted to the maximum transect length plus the extra 50 m. I used a GLMM to analyze if the distance to a water hole influenced the likelihood of a tree being marked. The response variable in the final model was marked and unmarked trees (1, 0), the explanatory variables were the random and recorded distances from the waterhole. I included site as a random factor, because I was not specifically interested in a site effect, which would otherwise cost six degrees of freedom in the model (Table 4).

I used a stepwise backward elimination procedure for model selection, where the least significant variable is removed until the model only contains significant variables (Zuur et al.

2009). A P-value <0.05 was considered as significant. All analyses were carried out in Rstudio version 3.2.1 (R Development Core Team 2008).

To determine the selectivity of species marked by the bears, a selection ratio index was calculated, comparing the 94 rubbed trees with the 243 unmarked trees. To determine the proportion of each species that had been rubbed, the number of trees rubbed was divided by the total number of rub trees. The number of times that a tree species was left unmarked was also divided by the total number of unmarked trees. The resulting proportions were divided by the total number of rubbed and unmarked trees to give a selection ratio. Values > 1 indicated a selection for that tree species, and values < 1 avoidance. Infinite values were found when the proportion of unmarked tree was zero and represented an undefined quantity (Table 5) (Manly et al. 1993).

Results

Overall, 22 transects were monitored for bear signs, 117 mark locations were recorded, and a total of 360 rubbed and unmarked trees were measured for DBH, height, canopy width and distance to the waterhole. All marked trees were found along bear trails leading to used waterholes, some as far as 2 km away. The results of a GLMM evaluating the effects that distance to water had on the likelihood of marking, showed a significant relationship ($\beta = -0.00079$, $SE = 0.00036$, $P < 0.001$) between the two factors, with bears preferring to rub trees closer to waterholes (Table 3). Negative estimates for 'distance to ...' variables (here, distance to water) indicate positive selection (Boyce et al. 2002) (Figure 4).

The 94 trees that were rubbed by bears included 19 different species; 20 pasallo, 7 chimulala, 7 vichayo falso, 6 hualtaco, 6 lucraco, 5 chilco, 4 higueron, 4 overo, 4 palo santo, 4 sapote, 3 cautivo, 3 vichayo, 3 tunga, 2 chaquiroz, 2 firn, 1 cerezo, 1 faique, 1 ficus, 1 tupla, and 10 unidentified. An additional 23 trees were found with only scratch and bite marks on the bark. We identified four additional species, lechero, frejolilo, palo blanco, and papaya silvestre, that were not marked by the bears. The site of the rub trees was the first variable to be removed from the model (all P-values > 0.37). The next variables to be removed were DBH ($\beta = -0.0236$, $SE = 0.0382$, $P = 0.5368$) and then the canopy width of the tree ($\beta = 0.0451$, $SE = 0.0881$, $P = 0.6080$). The final model only contained shrub height as a factor. The final GLMM investigating the defining characteristics of rub trees indicated that tree height affected the probability that a tree would be marked ($\beta = -0.3520$, $SE = 0.0795$, $P < 0.001$) (Figure 5).

Bears chose to rub smaller trees. The average height of a marked tree was $2.24 \text{ m} \pm 2.17$, ($n = 210$, mean \pm SD), and many of the rubs were on shrubs or trees in the earlier stage of life. Rub trees were close to the ground and had many branches. The average mean height that a bear rubbed at was $(0.87 \text{ m} \pm 0.51)$, ($n = 82$). The average mean DBH of rubbed trees was $(3.92 \text{ cm} \pm 5.99)$, ($n = 368$).

The majority of marked trees ($n = 94$ of 117), were used as a rub tree by the bears. Hair was present at 55 of the marked trees, scratch marks were found on 26, and bite marks were recorded on 7 of them. A selection ratio index comparing the 94 rubbed and 260 unmarked tree species

indicated selection for ten species; chilco, vichayo, chaquiroz, vichayo falso, cautivo, higueron, pasallo, chimulala, sapote and an unknown species (Table 4). The tree species that were avoided by the bear include tunga, hualtaco, overo, palo santo, lucraco, firn, cerezo, faique, tupla, ficus, lechero, papaya silvestre, frejolilo, and palo blanco. Several of the trees had scratch marks on branches over 3 m from the ground, suggesting that the bears might climb trees to leave marks (Figure 8). The broken branches of rub trees act as hair snags and half-broken branches have remained the same for many years (Figure 10, 11). The age of marks on trees varied between a few days to over five years old.

Discussion

The aim of this study was to gain an understanding of Andean bear selection of rub trees located in the Peruvian dry forest. I tested the hypothesis that Andean bears would select trees to mark that were (1) located closer to waterholes, (2) larger in size, and (3) contained physical characteristics that could aid in bear scent persistence and detection. I found that Andean bears preferred to rub shorter trees that were closer to water holes. Bears of Cerro de Venado showed a positive selection ratio for 10 of the 23 registered species of trees recorded. The site location of each water hole and the DBH of trees was not an important factor in Andean bear selection of rub trees. This is the first study investigating the selectivity of rub trees by Andean bears of dry forest habitat. Thus, I found support for hypothesis (1), no support for hypothesis (2), and the selection for tree species suggests some support for hypothesis (3), although potentially important physical characteristics were not identified.

Location is an important factor for bears when considering where to mark trees (Burst & Pelton 1983; Clapham et al. 2012; Clapham et al. 2013; Green et al. 2003; Nie et al. 2012). Andean bears in my study preferred to rub trees located close to water holes (supporting hypothesis 1). Studies on brown and American black bears show that bears marked in areas used frequently and most likely to disperse their scent (Clapham et al. 2013; Henderson et al. 2015). With limited water in the Peruvian dry forest, water holes act as a central point for Andean bear activity. Marking trees close to water could increase the chances of signal detection by other bears. Brown bears are thought to mark close to salmon streams as a way of signaling dominance or avoiding conflict (Clapham et al. 2012). Andean bears also could avoid the cost of conflict and intraspecific competition by marking close to water. Andean bears in cloud forests are reported to mark on trails at higher elevations located close to food and on ridgelines (Peyton 1994). However, the range in elevation of Cerro de Venado (< 1000 m) is small compared to cloud forest sites (>1500 m) (Cuesta et al. 2003).

I found that Andean bears selected trees to mark that were smaller in height than unmarked trees, thus not supporting hypothesis (2). This is in contrast to the literature on brown and American black bears, which choose mark trees that are large in diameter and size (Clapham et al. 2013; Green et al. 2003). Small trees allow bears to rub their body over the entire tree/shrub. Thus, Andean bears may have chosen smaller trees to rub, because they are easier to rub by walking over them. Camera trap photos and field team video of bears of Cerro de Venado show them marking on all fours (quadrupedal stance). This behavior can be described as the bear standing

over the shrub or tree in a quadrupedal stance, breaking branches, and rubbing their pelage onto the broken branches (Figure 9). These broken branches act as efficient hair snags and could help retain and disperse the bears' scent for longer periods. This is in contrast to the bipedal marks documented in brown and American black bears (Clapham et al. 2012; Green et al. 2003; Taylor et al. 2015), and Andean bear of cloud forests (Goldstein & Marquez 2004), where the bears stand erect against a tree and scratch, bite, and rub (Burst & Pelton 1983). This could be due to differences in the habitat and available trees, with Andean bears of cloud forests marking on larger trees. Marking on smaller trees, closer to the bears' nose level, could allow for a greater chance of detection by other bears using the trails, by maximizing the size of the odor field. Similarly, giant pandas urinate on a portion of the tree that is at nose level to aid in intraspecific communication (Nie et al. 2012).

The temperatures of the dry forest are extreme and when the sapote fruit is not in season, there is often a lack of energetically rich food (Appleton et al. 2009). Marking on substrates close to the ground could be a more energy efficient way for the bears to communicate their presence than standing on their hind legs (bipedal) and marking. Chemosignals can be expensive to produce (Gosling 1986), and this would allow the bear to allocate more energy towards finding food and water. Similarly, the energetically poor diet of pandas forces them to be efficient with their use of costly chemosignals (Nie et al. 2012).

Rub trees often had scratch marks, bite marks, and a series of depressions in the ground leading to the tree. These pede marks, were caused by bears repeatedly stomping and grinding their pads into the ground. Many of these prints have been around for a number of years and were observed at 15 of the rub trees. In brown and American black bears, pede marking is a way of depositing pheromones (Clapham et al. 2013; Henderson et al. 2015). This behavior has rarely been documented in Andean bears and further suggests the bears' use of chemical signals for communication.

The high presence of hair found at rub trees (55 of 117 trees) suggests that the rub trees are used frequently. After we had removed hair from broken branches of rub trees, more hair was often found later. Rubbing was the most common marking behavior found, as 94 of the 117 marked trees had been rubbed. The lack of scratch and bite marks found on trees is in contrast to the marking behavior of Andean bear in cloud forests (Goldstein & Marquez 2004). This difference can either reflect fundamentally different marking behaviors by the two populations, or be the result of a different diversity of tree species found in either habitat. Variations of marking techniques have also been observed between American black bears in the Smoky Mountains, which mainly left scratch marks (Burst & Pelton 1983), and populations in California, which use rubbing as their primary means of communication (Taylor et al. 2015). These differences in marking behavior can either be due to environmental constraints, or fundamentally different marking behaviors between species and populations (Green et al. 2003).

Ursids choose specific species of trees to mark (Clapham et al. 2013; Nie et al. 2012). Andean bears in my study area showed a high selection ratio for ten of the 24 tree species recorded, thus providing indirect support of hypothesis (3). The tree species with the highest selection ratio for marking was chilco. Chilco is a member of the Asteraceae family, which contains highly

aromatic trees. Bears could have been attracted to the strong scent of this species and preferred marking chilco, because of its odor. Marking a tree with a strong smell could add a strong smelling component to the bears' scent following scent-rubbing and more easily advertise the bears' presence (Gosling & McKay 1990). Brown bears and the giant pandas are believed to select trees based on their aromatic qualities and sap and resin properties which could hold the bears' scent longer (Clapham et al. 2013; Nie et al. 2012). Similarly, cervids select tree species to rub due to their physical characteristics (Johansson & Liberg 2000; Massei et al. 1999) and aromatic properties (Kile & Marchinton 1977). Rub trees with strong aromas, that were selected by Andean bear, could be used by conservation managers to encourage released Andean bears to remain within a release site or select habitat (Campbell-Palmer & Rosell 2011). Chilco is a species that is used by people for medicinal properties to help external inflammation (Salcedo-Ortiz & Almanza-Vega 2011). Bears of Cerro de Venando could rub these species of tree as a means of skin care. This behavior has been observed in American black bears in Quebec, which cover themselves in a sticky sap to deal with insects (Engel 2002), and brown bears in Greece, which rub against telephone poles covered in a creosote preservative that helps kill insects (Karamanlidis et al. 2010).

Vichayo had the second highest selection ratio among recorded tree species. Vichayo is in the *Capparaceae* family, which produces pungent mustard oils from glucosinolates when the plant is damaged (Matthäus & Özcan 2005). Bears could be attracted to this species due to the oils and strong smell that is released during rubbing (Figure 12). Vichayo falso was another species of tree with a high selection ratio by the bears. Vichayo falso is characteristic for its small size, and is often the only woody shrub with green leaves found in dry forests or coastal deserts (Iltis & Cornejo 2007). The characteristic small height of Vichayo falso could be the reason for the high selection ratio of this species. The presence of green leaves, which makes the tree conspicuous in the landscape, could also attract bears to Vichayo falso. The most commonly recorded tree species and one with the smallest selection ratio was Palo santo, and Andean bear of Cerro de Venando selected species of trees that were less common. Andean bears could prefer marking rarer species that stand out in the landscape as a way of increasing the chance of signal detection. Clapham et al. (2013), found that brown bears in British Columbia select rarer, conspicuous tree species to mark.

Andean bear populations are steadily declining, and habitat fragmentation and a lack of knowledge that can assist in their conservation are among the largest threats the bears face. The results of my study on rub tree selection can help to fill gaps in our knowledge about the ecology and behavior of Andean bears, which will allow for the development of realistic conservation plans. Financial constraints are another obstacle for Andean bear conservation in South America. The results of this study can be used to more easily locate preferred rubbing sites of Andean bears. This can lead to analysis of hair found at rub trees, which serves as a cost-effective way of carrying out genetic studies. Studies on brown bears have used rub trees to access population structure (DeBarba et al. 2010) or as records of presence for modelling abundance, population trends and density (Kendall et al. 2008).

The IUCN/SSC Bear Specialist Group, listed "unique and endangered habitats occupied by bears such as desert habitat" as a priority for study (Goldstein et al. 2008b). Peru's northern dry forests

are rapidly being reduced to a fragmented habitat. Andean bears in this delicate ecosystem depend on a small number of waterholes for their health and social communication. Disruption due to anthropogenic land use and free-ranging cattle could damage the ecological function of these sites for the bears. In the next watershed to the south, Chapari, intensive cattle grazing and timber extraction left many areas of the reserve degraded in floristic and forest structure (Linares-Palomino & Ponce-Alvarez 2009). Cattle grazing and human disturbance in the Bijnor Division of India's Rajaji-Corbett National Park, are seen as the main causes of tiger (*Panthera tigris*) extinction in this region (Johnsingha & Negib 2003). Cattle could contaminant water holes and introduce a number of diseases to bears (Bengis et al. 2002). Continued grazing pressure by cattle could also result in human-bear conflict, as experienced in other parts of the Andean bears range (Goldstein et al. 2006).

Much of the Andean bear's range, including the dry forest of Northern Peru, is threatened by extractive mining development (Garcia-Rangel 2012). This not only leads to the isolation of Andean bear populations (Garcia-Rangel 2012), but also results in the release of many anthropogenic chemicals that can disrupt the chemical information transfer in a range of animals (Lüring & Scheffer 2007), even low levels of pesticides have been found to alter scent marking behavior in mice (Saal et al. 1995). These environmental disturbances can weaken the persistence and detection of chemical signals left by animals (Lüring & Scheffer 2007). Scent marks and rub sites promote the genetic flow in a fragmented habitat, by encouraging animals movement along corridors (Swaigood et al. 1999). These disturbances could have far reaching consequences for Andean bears, such as decreasing fitness, hybridization or failure to select highest quality mate (Angeloni et al. 2010), and threatens not only their communication system, but possibly even their genetic variability and evolution (Swaigood 2007).

Conclusion

This study presents the first insight into how bears of the Peruvian dry forest communicate with each other. Selection of rub trees by bears was based on the size (preferred smaller trees), species, and the distance of trees from water holes (preferred trees closer to water). These rub site characteristics are thought to have been selected by Andean bears because they promote the detection and persistence of chemical signals to conspecifics. Waterholes are a scarce resource in the dry forest, and a small number of these serves as the only source of water for this unique population of Andean bears. The endangerment or loss of these waterholes and trees from the landscape could impede the bears' ability to effectively communicate, making it difficult to find other conspecifics during the breeding season.

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Table 1: The mean, variance, and standard deviation of the diameter at breast height of trees rubbed by Andean bears, unmarked trees, and the height of the rub in the dry forest of Peru.

	Mean	Variance	Standard Deviation
Height of rub	0.87 m	0.262	0.511
Height of rub tree	2.24 m	4.75	2.17
DBH marked trees	3.92 cm	35.88	5.99
Height of unmarked trees	4.09 m	6.51	2.55
DBH unmarked trees	8.91 cm	76.24	8.73

Table 2: The final generalized linear mixed model, investigating tree height as a variable in Andean bear selection of rub trees in the dry forests of northern Peru. The variables site, DBH, and canopy cover were excluded from the final model due to the high p values.

	Estimate	Std. Error	Z value	Pr (< z)
(Intercept)	0.6636	0.4430	1.498	0.134
Tree Height	-0.3520	0.0795	-4.428	9.53e-06***

Table 3: Results of a generalized linear mixed model investigating the distance to water as a factor influencing tree-rubbing behavior by Andean bear in the Peruvian dry forest. The random factor used in the final model was site. Note that negative estimates for ‘distance to water’ landscape variables indicate selection for that specific variable.

	Estimate	Std. Error	Z value	Pr (< z)
(Intercept)	0.1967	0.1558	1.262	0.2069
Distance to water	-0.0007	0.0003	-2.249	0.0245*

Table 4: Table displaying the ratios of trees rubbed by Andean bears in the Peruvian dry forest.

Tree species	Rubbed trees	Unmarked trees	Proportion marked	Proportion unmarked	Selection Ratio
chilco	5	1	0.05	0.003	13.82
vichayo	3	1	0.03	0.003	8.29
unknown	10	5	0.10	0.01	5.53
chaquiroz	2	2	0.02	0.007	2.76
vichayo falso	7	8	0.07	0.03	2.42
cautivo	3	4	0.03	0.01	2.07
higueron	4	6	0.04	0.02	1.84
pasallo	20	31	0.21	0.11	1.78
chimulala	7	11	0.07	0.04	1.76
sapote	4	7	0.04	0.02	1.58
tunga	3	9	0.03	0.03	0.92

hualtaco	6	22	0.06	0.08	0.75
overo	4	20	0.04	0.07	0.55
palo santo	4	113	0.04	0.43	0.09
lucraco	6	0	0.06	0	∞
firn	2	0	0.02	0	∞
cerezo	1	0	0.01	0	∞
faique	1	0	0.01	0	∞
tupla	1	0	0.01	0	∞
figus	1	0	0.01	0	∞
lechero	0	5	0	0.01	0
papayo silvestre	0	5	0	0.01	0
frejolilo	0	1	0	0.003	0
palo blanco	0	2	0	0.007	0

Figure 1: IUCN distribution map for Andean bear and location of study site ‘Cerro de Venado’ in northern Peru (Goldstein *et al.*, 2008).



Figure 2: Photos of a female Andean bear 'Laura' after drinking from the 'Debujos' waterhole (Jack Kleiner, 2013, Spectacled Bear Conservation Society)

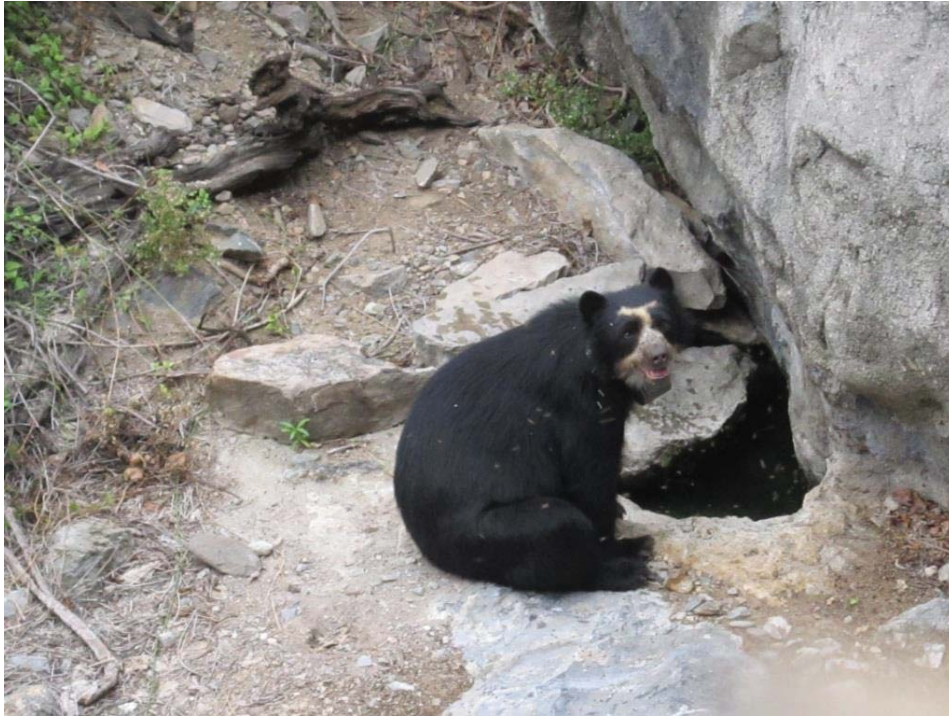


Figure 3: Location of water holes in the field site in the order they were visited; (A) Debujos (B) Mayascon (C) Calaboso (D) Agua del Puente (E) Agua del Oso (temporary) (F) Agua del Oso (permanent) (G) Sogas.

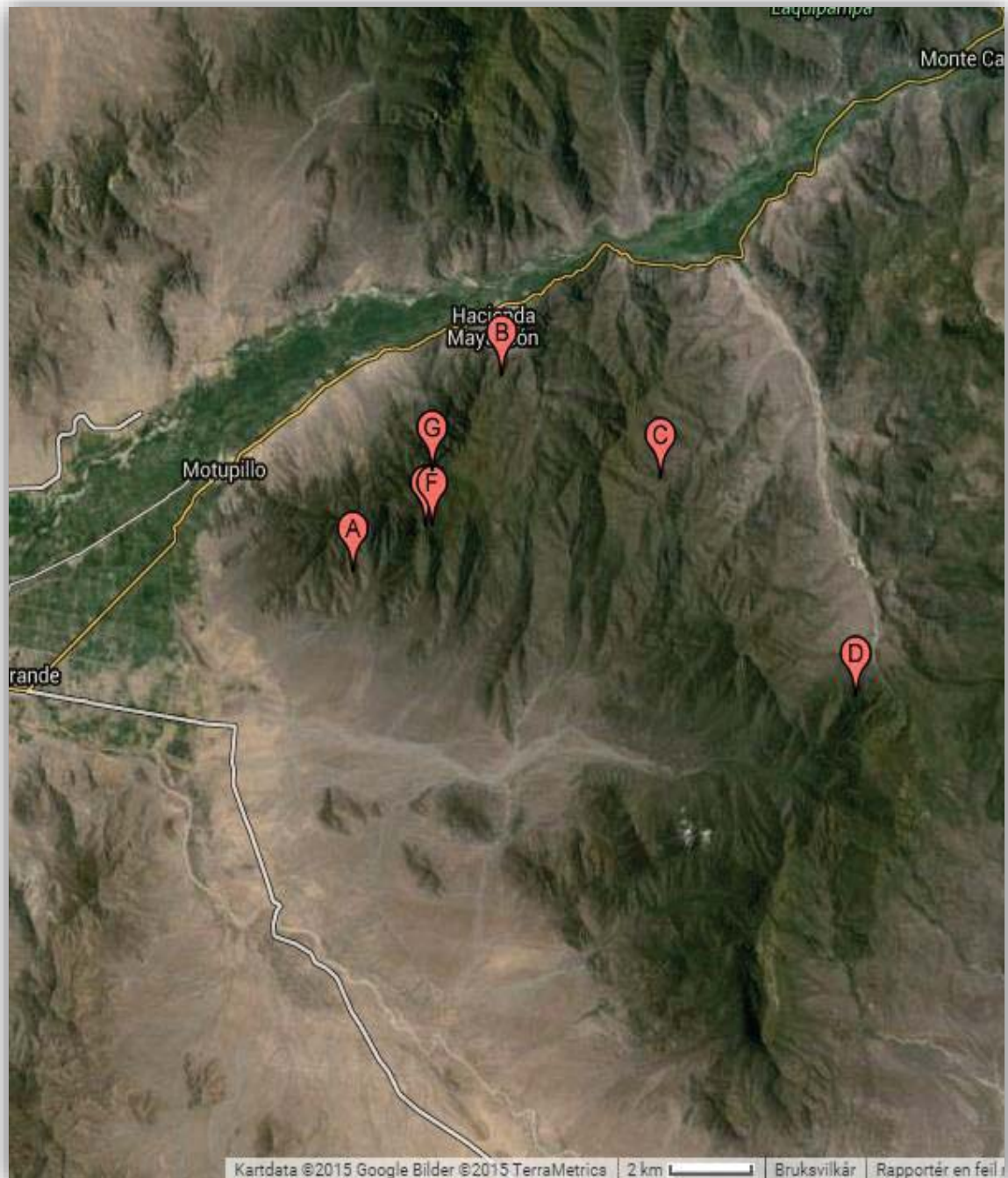


Figure 4: The probability that Andean bears of the Peruvian dry forest select a tree in relation to the distance to the nearest waterhole, irrespective of the random factors of site.

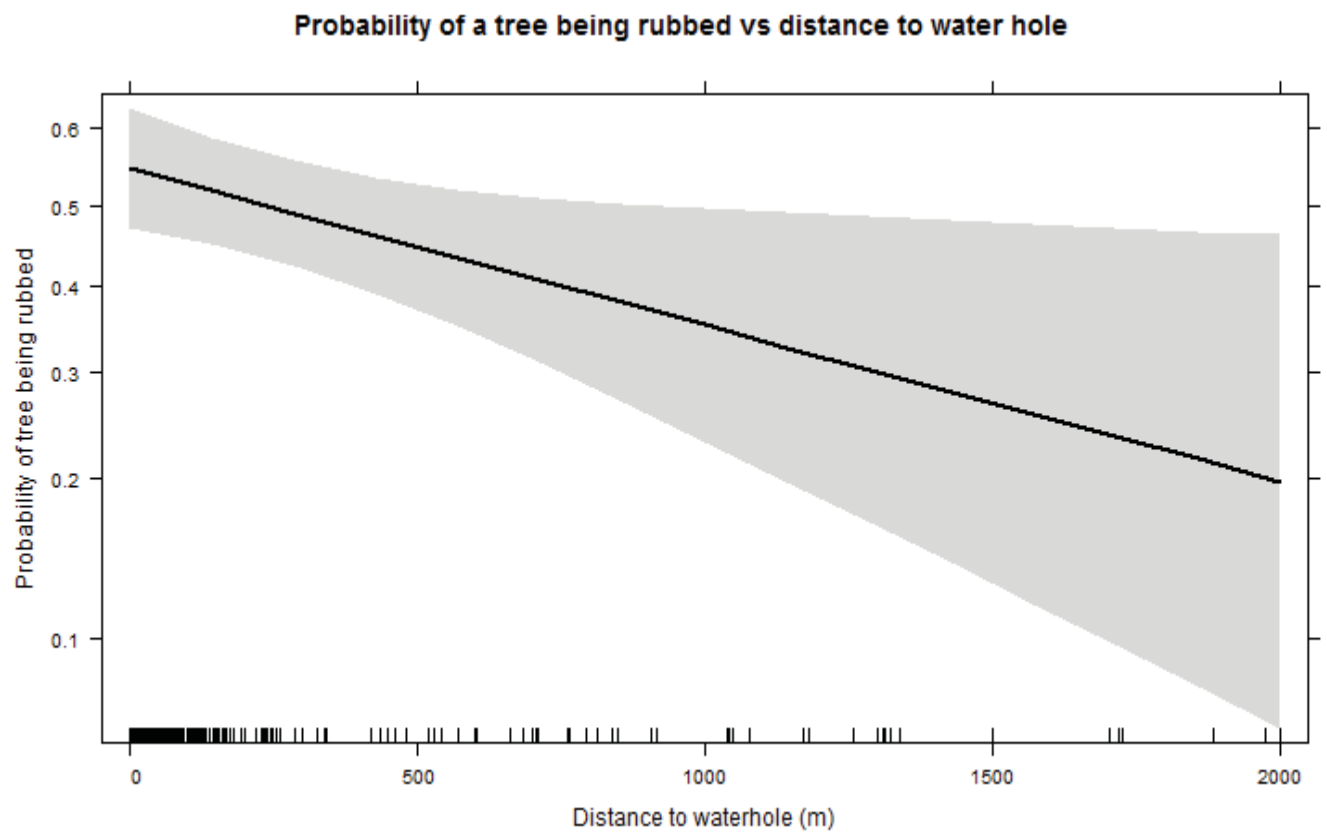


Figure 5: Plot displaying the final model of a GLMM investigating the effect of tree height on the probability of a rubbing response by Andean bears in the Peruvian dry forest.

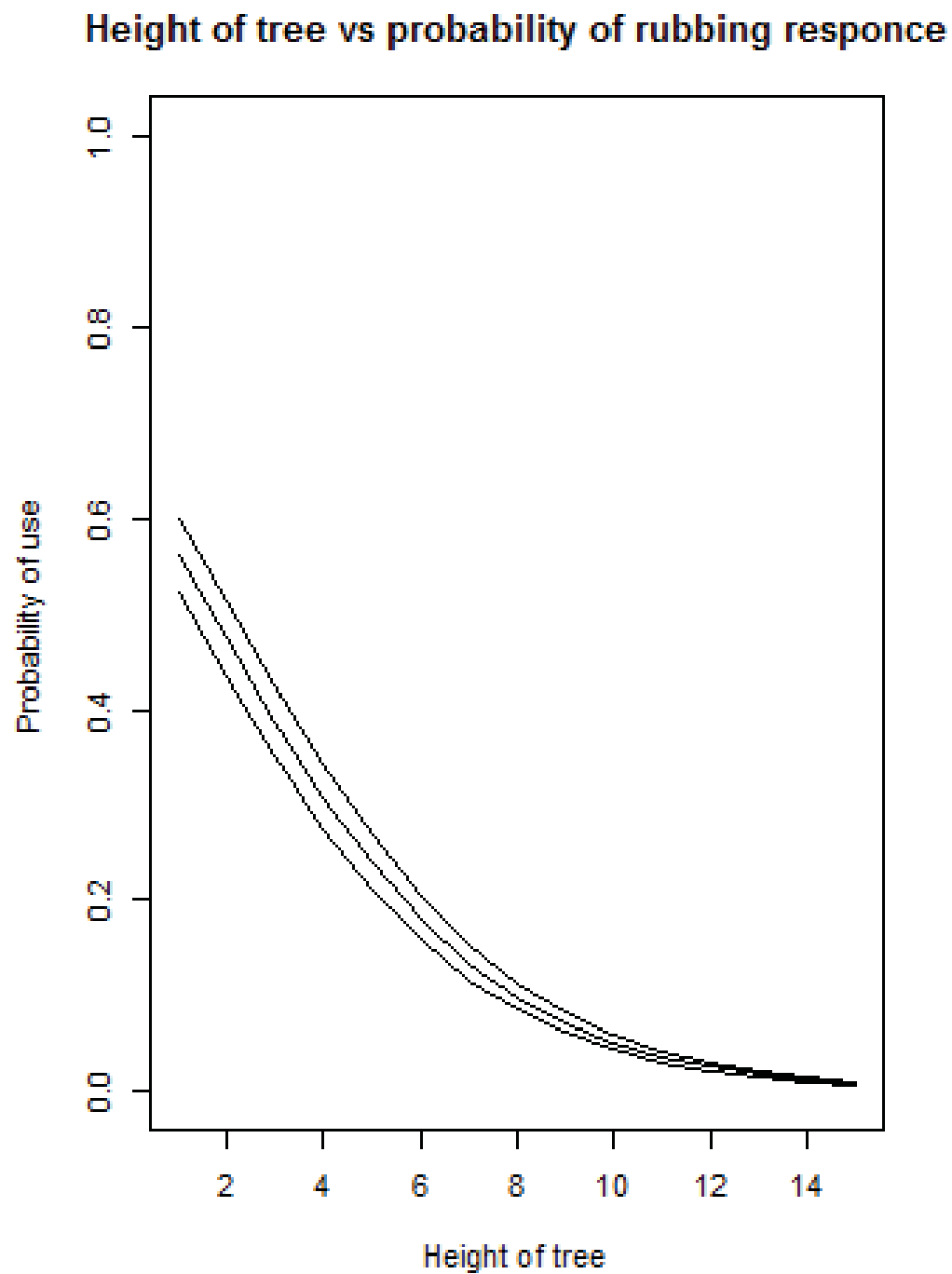


Figure 6: Histogram of diameter at breast height (DBH), canopy width, and height of rub trees used by Andean bears and the surrounding unmarked trees in the Peruvian dry forest.

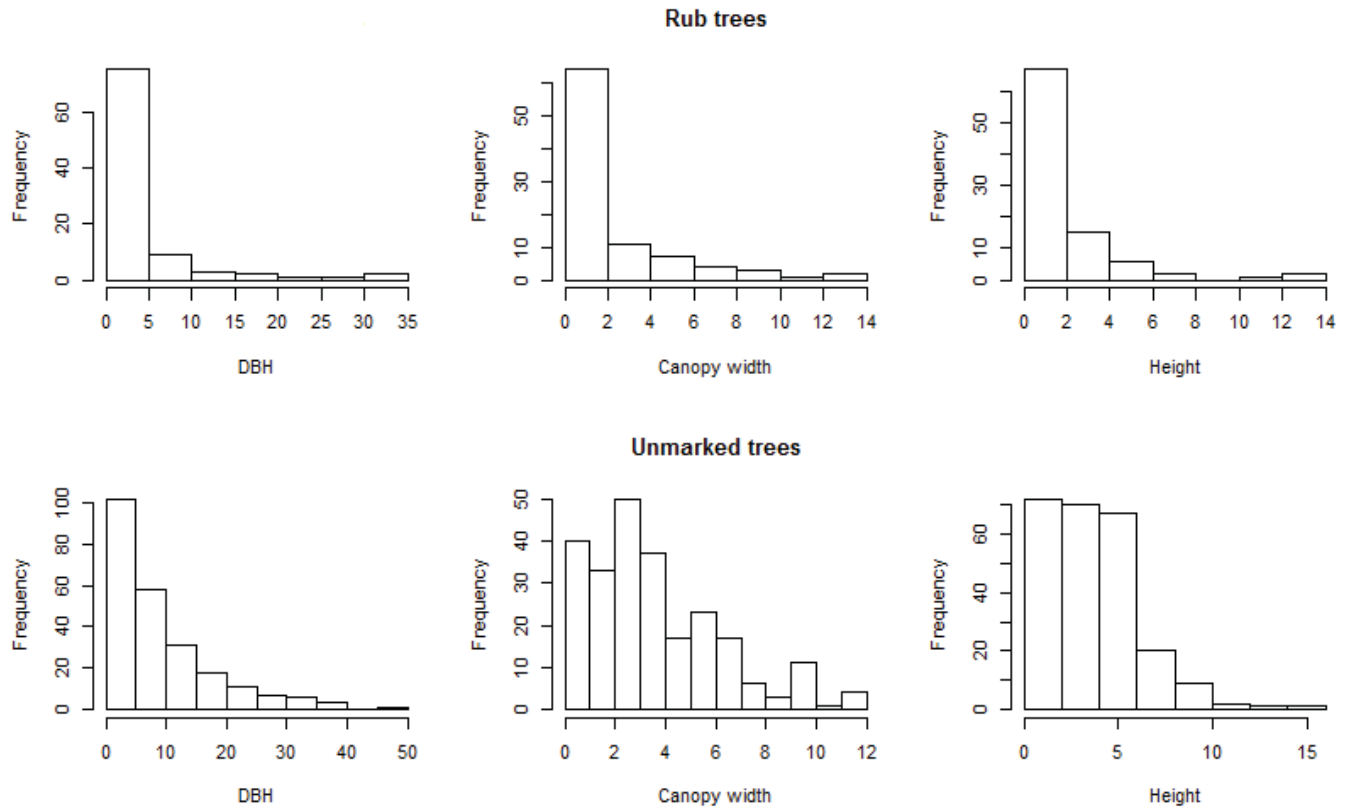


Figure 7: Scatter plot displaying the relationship between diameter at breast height (DBH), canopy cover, and height of rub trees (blue) used by Andean bear and the surrounding unmarked trees (red) in the Peruvian dry forest. This plot shows that trees selected by Andean bears for rubbing had smaller heights than the available unmarked trees.

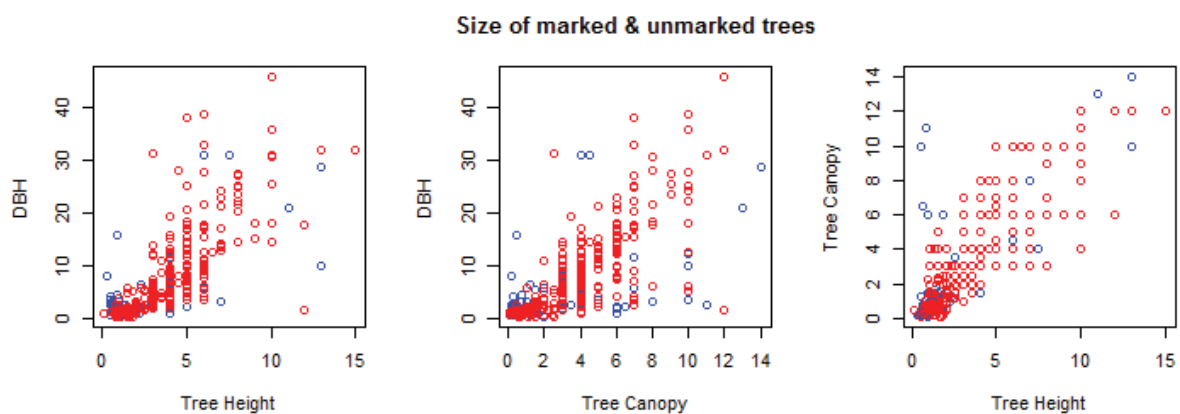


Figure 8: Scratch marks from an Andean bear found 3 m up in a tree.



Figure 9: Demonstration of Andean bear marking behavior on a rub tree.



Figure 10: Scale of one of the shrubs used for rubbing by Andean bears.



Figure 11: Example of a Andean bear hair snagged on a branch.



Figure 12: Example of fresh scratch marks and bite marks from Andean bears found on one of the marked trees.



Appendix

Andean Bear Natural History & Ecology

Today's distribution and abundance of ursid species is a reflection of an evolutionary path that began around 20,000,000 years ago during the late Oligocene and early Miocene, when bears evolved from smaller ancestors known as the dawn bears (*Ursavus elmensis*) (Macdonald 2001 ; Stirling & Derocher 1990). These eventually gave rise to eight extant species of bear that exist today in three distinct lineages, Ailurpinae, Tremarctinae, and Ursinae. Bears in these lineages occupy habitat ranging from high arctic to lowland tropical forests and include two of the worlds' largest terrestrial carnivores, the polar bear (*Ursus maritimus*) and the brown bear (*Ursus arctos*) (Stirling & Derocher 1990).

The Andean or Spectacled bear (*Tremarctos ornatus*), is the last living species of short faced bear from the Tremarctinae lineage and the only member of Ursidae in South America (McLellan & Reiner 1994). Historically Tremarctinae is the only lineage of bears that is endemic to the American continent, with a range that once stretched from Alaska to Patagonia. *Tremarctos floridanus*, an ancestor of the Andean bear, lived in North America during the late Miocene to early Pliocene (7.34 – 4.26 million years ago). It is believed that Andean bears evolved from *T. floridanus* during the late Pleistocene or early Holocene Epoch (0.13 million years ago to recent times) (McLellan & Reiner 1994). Tremarctinae bears are thought to have arrived in South America during the early Pleistocene, around 1.8 million years ago (Cavelier et al. 2010). The oldest known fossils of Andean bear were found in Chaquil Cave, in north-central Peru (Stucchi et al. 2009).

Physical Description

The Andean bear is one of the smallest species of bears and, like other ursids, shows sexual dimorphism in size. Adult males measure 1.12 to 2.22 m head-to-body in length and weigh between 80 to 175 kg, and females are two thirds of this size (Cavelier et al. 2010; Garcia-Rangel 2012; Peyton 1980; Peyton 1999; Stirling & Derocher 1990). Female bears also lack the presence of a well developed lamboid crest that can be found on male skulls (Mondolfi 1971; Peyton 1999). The bear's pelage is usually black, but it can have dark red to brown variations to it. The common name for Andean bear, the 'spectacled' bear, refers to yellowish markings often found encircling one or both eyes. Markings vary between individual bears and can be found on the forehead, muzzle, under the chin, and even extending down the chest (Emmons 1997; Mondolfi 1971; Peyton 1999) (Figure. 1).

Andean bears have stocky bodies, small rounded ears, short thick necks, and a small tail hidden in fur. In relationship to their head and body size, Andean bears have the shortest muzzle length and largest zygomaticomandibularis muscle of any ursid (Figueirido et al. 2011; Peyton 1999). Andean bears have fourth premolars with blunt lophs that are unlike those of other bears. Their

short muzzle, the presence of this pronounced muscle, and its characteristic fourth premolar enable the bear to chew tough fibrous foods (Christiansen 2007 ; Davis 1955 ; Peyton 1999).

Distribution

Andean bears have a distribution that extends from Venezuela to the Bolivia-Argentina boarder, (Figure 2) covering 38 degrees latitude (11 ° N to 27 ° S) (Cavelier et al. 2010; Peyton et al. 1998). This elongated and narrow range is only 200-650 km wide, but more than 4,600 km long (Kattan et al. 2004; Peyton 1999). Andean bears occur in both the Sierra de Perijá and Cordillera de los Andes of Venezuela, all three ranges (Occidental, Central and Oriental) of the Colombian and Peruvian Andes, both the eastern and western slopes of the Ecuadorian Andes, and the eastern slopes of the Bolivian Andes (Garcia-Rangel 2012; Mondolfi 1989; Peyton 1999; Ríos-Uzeda et al. 2006). Andean bears occupy 260,000 km² of forested habitat in Venezuela, Colombia, Ecuador, Peru and Bolivia (Peyton 1999; Rios-Uzeda et al. 2007). In addition, its presence has been debated in Panama and Argentina (Goldstein et al. 2008a; Peyton 1999). The distribution of Andean bears today, is largely shaped by anthropogenic uses of the land. This has resulted in a range that is isolated and restricted to small patches of habitat that have avoided the advancement of agriculture (Garcia-Rangel 2012).

Habitat

The Andean bear is known as a landscape species, i.e a species that require large home ranges to meet all their needs (Sanderson et al. 2002), as they have a requirement for continuous habitat along altitudinal gradients and over large areas, following seasonal patterns of food resources (Kattan et al. 2004). (Garcia-Rangel 2012; Kattan et al. 2004; Ríos-Uzeda et al. 2006). During the dry season, when there is little fruit available in the forest, bears show a preference for the use of high elevation paramo, where there is an abundance of food, such as bromeliads (Kattan et al. 2004).

Andean bears in Bolivia avoid forest below 1000 m and show a clear preference for higher elevation forest vegetation types (elfin and upper montane humid forests) up to 3700 meters above sea level. This is due to less competition and more food resources found in higher elevation. In Peru bears are most often found living in paramo and cloud forest between 1,675 and 2,900 masl. The annual rainfall of 2 -7 m in this habitat supports the greatest species diversity in Peru (Peyton 1999). In the Northern Andes (Venezuela, Colombia, Ecuador), the ideal altitudinal extent of forested habitat for Andean bear is between 1,000 and 3,000 masl (Kattan et al. 2004).

Diet

The Andean bears' diet is primarily vegetarian and largely made up of terrestrial and arboreal epiphytic bromeliads (Cuesta et al. 2003; Kattan et al. 2004; Paisly & Garshelis 2006; Ríos-Uzeda et al. 2006; Troya et al. 2004). There are 22 different species of Bromeliaceae found in the diet of Andean bears (Peyton 1980). Bromeliads act as an important source of nutrition for bears, as they contain carbohydrates, fat, and protein (Goldstein 2004). They also act as a valuable source of water for Andean bears in the scrub desert and steppe habitats, with bromeliads containing more than a liter of water (Peyton 1980). In the Oyacachi River Basin, Ecuador, bears frequently use the grass paramo for bromeliads between May-June and September – December. However in Antisana, Ecuador bears use this habitat for food between February and July (Troya et al. 2004) and between February and April in Peru (Peyton 1980). In Bolivia bromeliads are eaten by the bear year round, while fruit is only eaten from March-October (Paisly & Garshelis 2006).

The Andean bear moves great distances throughout their home ranges depending on the fruiting periods and seasonal variability of the species they consume (Cuesta et al. 2003). After bromeliads, fruits are the most frequent item in the diet of Andean bear and opportunistically consumed depending on their availability (Paisly & Garshelis 2006; Troya et al. 2004). These fruits range from the aqueous, carbohydrate-rich fruits of *Ficus* spp, *Cecropia* spp, and ericaceous shrubs, to the lipid-rich fruits of Lauraceae (*Ocotea* spp, *Nectandra* spp, and *Persea* spp), oak *Quercus* acorns, and palms (*Euterpe* spp, *Pestoea* spp) (Cavelier et al. 2010; Ríos-Uzeda et al. 2006). The months of the year that fruit is most abundant changes depending on the biogeographic region (Cavelier et al. 2010). In Oyacachi River Basin, Ecuador, fruits are available in montane cloud and upper montane between January –February and July- August (Cuesta et al. 2003). Peyton (1980) identified 31 species of fruiting tree that represented 28.7% of the bears' diet (Peyton 1980).

Behavior

There is very little information on the behavior of Andean bear. The secretive and solitary nature of Andean bear and the dense cloud forest they most often inhabit make in-depth behavior studies difficult. To date most field work has been focused on sign-based surveys, local knowledge, and recent genetic analysis of hair. Only two studies in Bolivia and Ecuador have documented on a small scale the movement patterns of wild and reintroduced bears (Castellanos 2005; Paisley 2001) and observational studies have only been conducted on captive animals in zoos (Molloy 1989; Peel et al. 1979).

Like other bears, Andean bears are generally solitary, although groups of up to 9 bears have been observed feeding together in *Opuntia* cactus groves and maize fields (Servheen et al. 1999). During the summer months in the Peruvian dry forest, bears feeding on sapote fruit, show some tolerance towards each other. Up to 5 bears have been observed feeding in close proximity to one another and 11 within 3.8 km of each other (Appleton et al. 2009). The sapote fruit has a great impact on the behavior of Andean bear. During the fruiting season of between December and

March, bears will travel along trails from tree to tree pulling down fruit. They can travel great distances and across a number of different valleys in one day. Sapote is found in the lower elevations, and bears periodically travel down to feed during the early morning. When the heat is most extreme in the middle of the day, bears retreat to higher elevations, where they drink and bathe at water holes and build daybeds. Bears find steep terrain to make daybeds, and construct them by bunching broken sticks into nests on the ground. During nights bears can be found on cliff edges between 600 – 1100 m (Appleton et al. 2009). When sapote fruit is not available, during the winter months between April- November, Andean bears of Cerro de Venado eat the core wood of trees. The bears travel up to the high elevations between 600-1100 m to access this resource. Bears hold the tree with their paws while they bite and rip through the outer bark. This allows them to suck out the nutrients of the heart wood. There is little variation between the time when bears feed during the winter months (6-12) and summer months (6-11) (Appleton et al. 2009).

Andean bears are primarily terrestrial, but are considered one of the most arboreal members of Ursidae (Mondolfi 1971; Peyton 1999). Andean bears will climb trees to sleep, forage, or as an eversion technique (Goldstein 2002). In the cloud forest of Ecuador bears climb to the tree tops to reach the hearts of bromeliads of the species *Areaceae*. The bears use their paws to break branches that cannot support their weight, and collect the fruit from the forest floor (Castellanos et al. 2001). This behavior allows for natural regeneration of the forest and is thought to greatly modify the microclimate conditions of the lower strata (Rodríguez et al. 1986). Andean bear have been reported as both livestock killers and scavengers in parts of their range. Predation occurs in the remote grassland ecotones near large tracts of forest. The bears attack by jumping on cattle's back and scratching and biting the back and neck (Goldstein et al. 2006). Then the cattle are wrestled to the ground with a tripping motion (Laguna 2013). To hide and consume the carcass, bears create trails and tree nests by assembling broken and bent branches on the forks of tree branches. Tree nests have strongly been associated with carcass feeding sites in Venezuela and Ecuador (Goldstein 2004). The bears drag carcasses from one feeding site to another several times (Goldstein 2002; Goldstein et al. 2006). Cattle predation is a behavior primarily carried out by male bears. However, raiding maize fields is a behavior that is common for all sexes and age classes of Andean bear. Bears raid fields when the maize is ready for harvest and continue for three weeks after that. The bears target fields that are isolated or close to the forest edge and either eat right there or collect cobs and bring them to a more secluded spot (Paisley 2001; Peyton 1980).

Unlike most bears, Andean bears do not hibernate, perhaps because there is food available all year round (Peyton 1999). They are considered energy maximizers, as they are asocial and spend most of their time foraging. Generally, activity starts at 6:00, peaks between 9:00 and 18:00, and drops after that (Castellanos 2003; Castellanos 2005; Paisley 2001). The absence of a functional tail in bear species is thought to be due to their solitary nature and lack of communication displays (Stirling & Derocher 1990). Andean bears rarely communicate with vocalization apart from females with cubs. Andean bear vocalization can be described as a humming or an 'rrr' (Appleton et al. 2009; Peters et al. 2007).

There have only been a few studies on the home range sizes of Andean bears and information is scarce (Garcia-Rangel 2012). Estimates have been made from values based on other bear species, and data collected from a small number of wild and reintroduced bears (Castellanos 2005; Castellanos 2011; Garshelis 2011; Kattan et al. 2004). Studies on bears using telemetry in Bolivia and Ecuador show that minimum home range of the bears varies from 10 to 160 km² (Castellanos 2011; Paisly & Garshelis 2006). However activity patterns of Andean bears vary between geographic area, family, unit, sex, age, and individual (Castellanos 2011; Paisly & Garshelis 2006). In Ecuador, the annual home range of males (126 km²) and four times larger than that of females (36 km²). A large degree of home range overlap has also been observed between male and female bears (Castellanos 2011). Bears in Bolivia are reported to have larger home ranges in the wet season than the dry season (Paisley 2001).

Reproduction

There is very little information available on the reproduction of wild Andean bears (Enciso & Vásquez 2007). Like all bears, they are polyestrous and capable of embryonic diapyses (delayed implantation). (Peyton 1980; Spady et al. 2007). Courtship lasts for a week and is associated with vocalizations, aggressive behavior, playful fights, and games. The breeding pair emits high-pitch growls during coitus, which lasts for 12-45 minutes with multiple copulations (Appleton et al. 2009; Garcia-Rangel 2012). According to Peyton, 1980 wild Andean bears have a gestation period of 160 to 255 days (Peyton 1980). However, the period of gestation in bears is high variable and difficult to measure due to diapauses (Garshelis 2009).

Births are timed 2 to 3 months before the fall of heavy fruit during the rainy season, which allows cubs to be the appropriate age to eat ripe fruit (Peyton 1999). In Ecuador, bears of the Intag region are reported to synchronize their parturition with the growth of maize from March to July (Castellanos 2010). Andean bear can give birth to 1 to 4 cubs, depending on the females' weight and the availability and diversity of food (McDonald & Fuller 2001). This can be seen in Columbia to Northern Peru, where a greater diversity of food supports larger litter sizes than other parts of the bears range (Peyton 1999). Survival of newborns in captivity is low (59 – 64%), higher during reproductive years and even lower when the bears reaches 15 – 25 years old (Kohler et al. 2006). The life span of males and the chances of survival are greater than females (Rodríguez-Clark & Sánchez-Mercado 2006). In the wild females will find caves and dens, where they stay for three to four months. All bears are born altricial, so bear dens are important parts of bear reproductive ecology (Van-Horn et al. 2013). Females will lactate for one year and provide maternal care for up to two years (Mondolfi 1971). Captive females have come back into estrus within 4 to 6 weeks after weaning. The availability of food and the weight of bears can determine when they reach sexual maturity. Females give birth for the first time when they are 5 years. Female fertility reaches its prime in captive bears between 4 -14 years old. This peaks much higher and faster than males, which stay fertile for most of their life (Rodríguez-Clark & Sánchez-Mercado 2006).

Threats

The low reproductive rates of Andean bears and the array of anthropogenic threats they face throughout their range has given the bear a IUCN listing of vulnerable to extinction (Garcia-Rangel 2012; Goldstein et al. 2008b). The greatest threats to Andean bear are habitat loss, fragmentation, poaching, and a lack of knowledge about the bear's distribution and status (Goldstein et al. 2008b; Peyton 1999; Rodríguez-Clark & Sánchez-Mercado 2006). Due to the increasing value of Andean highlands as agricultural areas, there has been a continuous reduction of available habitat for the bear in the last 30 years (Cavelier et al. 2010; Herrera et al. 1994; Peyton et al. 1998). Poorly made land reforms and a lack of land ownership has forced many farmers into bear habitat. Through farming practices (i.e. monocultures, slash and burn, shifting cultivation, extensive highland grazing), farmers inflict damage to bear habitat that is irreversible, due to the fragile ecosystem (Garcia-Rangel 2012; Peyton 1999). It is estimated that less than 8% of the forests of the western Andes remain, making it one of the most heavily damaged ecosystems on earth (Castellanos 2010). Development plans and a rise in the population throughout the Andes threatens the connectivity of bear habitat (Goldstein et al. 2008b). Anthropogenic uses of the land, such as mining, oil extraction, logging and the development of infrastructure such as roads, dams, gas pipes and power lines, have all resulted in the isolation and fragmentation of bear populations (Garcia-Rangel 2012; Peyton 1999). During 20 years of road building in Peru (1960-80), hunters estimate that Peru's bear populations declined by a third (Peyton 1981). Farmers are given easy access points to bear habitat from roads, that allow them to establish and expand settlements and agriculture (Peyton et al. 1998). Roadless areas of the eastern Oriental Andes Slopes and parts of the bears range in Peru are the only area <1800 m where Andean bear have not been displaced from (Peyton et al. 1998).

The increase in the human population throughout the bears' habitat, and the wide range that Andean bears travel, causes an increased number of interactions with people at reserve boundaries (Peyton et al. 1998). The disappearance and deaths of livestock are often blamed on Andean bear (Goldstein et al. 2006). In other regions the bears are blamed for raiding maize fields (Castellanos 2011). These negative perceptions often lead to poaching of the bear by local residents, who enlist the help of hunters (Cavelier et al. 2010; Goldstein et al. 2006; Peyton et al. 1998). Between 1992 and 1997, Jorgenson and Sandoval (2005), reported 34 kills from 36 maize-raiding and 26 cattle-eating events (Garcia-Rangel 2012; Jorgenson & Sandoval 2005). It is estimated that a total of 200 bears a year are poached across the Northern Andes (Venezuela, Colombia, Ecuador and Northern Peru), but an accurate figure across the bear's entire range is not known (Garcia-Rangel 2012; Rodríguez et al. 2003). The capture of bear cubs for the pet trade is another major threat to Andean bears (Paisley 2001). Bears are also killed by poachers and peasants in an attempt to make money from body parts used in traditional medicine (Cavelier et al. 2010; Peyton et al. 1998). Bear parts are traded between local people throughout the bear's range, with sales mainly isolated to country borders (Paisley 2001). The demand for bear parts also comes from the Asiatic market and takes place in Venezuela, Colombia and Ecuador. In the Cayambe-Coca and Cotacachi-Cayapas Ecological Reserves, Ecuador, Korean businessmen have offered farmers 115 US dollars for the illegal trade of Andean bear gall bladders (Feng et al. 2009; Figueroa & Stucchi 2009; Peyton et al. 1998; Peyton 1999).



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