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Is the banana ripe? Andean bear–human conflict in a protected area of Colombia

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Abstract: The Andean bear (*Tremarctos ornatus*; bear) is endemic to the tropical Andes Mountains of South America. Previous assessments predict that bear populations will decline by >30% in the next 30 years. The species may face the greatest threats within its historical distribution in Colombia where rapid agricultural expansion into natural habitats is increasing human–bear conflicts. Between April 2017 and March 2018, we studied bear feeding behavior on plantain (*Musa sapientum*) and banana (*M. paradisiaca*) crops within the Barbas-Bremen protected area in the central mountain range of Colombia to describe the magnitude of crop damage, economic losses, and spatial distribution of feeding sites where human–bear conflicts would most likely occur. We also identified all affected farmers and used structured interviews to determine their attitudes toward the bears and their conservation. We recorded 237 damaged plants and identified 57 bear feeding area locations on 9 farms. Bear damage consisted of bites to the trunk of each plant and consumption of the centers. The damage polygon covered 198 ha, and it was located in the northwestern portion of the protected area. Although we estimated that <1% of the total plantain and banana production in the area was lost due to bear depredation, surveyed farmers expressed negative attitudes toward bears and conservation groups seeking their protection. Our research is the first estimation of the magnitude of crop consumption by bears and social and economic dimensions of damage caused by the species in Colombia. Our research also provides insights on how human–bear conflicts may be mitigated in the study area.

Key words: Andean bear, banana, Colombia, crop damage, human–wildlife conflict, *Musa* spp., natural reserve, plantain, *Tremarctos ornatus*, wildlife conservation

The Andean bear (*Tremarctos ornatus*; bear) is endemic to the tropical Andes Mountains of South America (Figure 1). It is distributed in Venezuela, Colombia, Ecuador, Peru, Bolivia, and Argentina, and its historic range includes elevations of 200–4750 m (García-Rangel 2012, Cosse et al. 2014; Figure 2). Although the bear is the only extant species of bear in South America, a lack of knowledge about its distribution, population status, and natural history has limited the effectiveness of conservation initiatives (Velez-Liendo and García-Rangel 2017). Compared to other bear species (e.g., *Ursus* spp., *Melursus* spp., *Ailuropoda melanoleuca*, etc.), conservation, research, and scientific data on the Andean bear's natural history are considered rare and difficult to obtain (Can et al. 2014). The paucity in ecological information is attributed to limited access to economic resources for research, inaccessibility of the species' habitat, and its elusive nature (García-Rangel 2012).

According to the International Union for Conservation of Nature (IUCN), bear populations are projected to decline by >30% within 30 years (Velez-Liendo and García-Rangel 2017). Moreover, bear habitat within the historic range of the species is declining at a rate of 2–4% per year (Velez-Liendo and García-Rangel 2017). The species is cataloged by the IUCN Red List of Threatened Species as Vulnerable under criteria A4cd (Velez-Liendo and García-Rangel 2017). In Colombia, the species is considered Vulnerable (Rodríguez-Mahecha et al. 2006, Ministry of Environment and Sustainable Development 2017).

Colombia has been identified as the country where the species faces the greatest threats

Figure 1. Adult Andean bear (*Tremarctos ornatus*) reported in the mountain ranges of Colombia, 2018.

within its distributional range (Rodríguez-Mahecha et al. 2006). Bear habitat located adjacent to the most populated and developed areas of the country are becoming increasingly fragmented, resulting in isolated populations (Kattan et al. 2004, Rodríguez-Mahecha et al. 2006, Correa-Ayram et al. 2020). Moreover, the peace agreements with the Fuerzas Armadas Revolucionarías de Colombia-Ejercito Popular (Revolutionary Armed Forces of Colombia; FARC-EP) guerrillas are contributing to the rapid expansion of the agriculture into bear native habitats (Ocampo-Peñuela and Winton 2017, Correa-Ayram et al. 2020). Agricultural expansion into the Andean forests of Colombia has also increased human–bear conflicts (Correa-Ayram et al. 2020).

The most common dietary items of bears in the wild include succulent plants from the Bromeliaceae and Arecaceae families (Goldstein 2004, Troya et al. 2004). There is a considerable diet variation among sites, and even within sites, depending on resource availability (Figueroa 2013*a*). When food resources are depleted due to habitat degradation, bears tend to increase interactions with human communities, generating conflicts consuming crops and potentially predating livestock (Jorgenson and Sandoval 2005). In agriculture areas, the bears typically consume mainly plant materials such as fruits, succulent plants, and occasionally meat and carcasses (Troya et al. 2004, Castellanos et al. 2005, Figueroa 2013*a*, Parra-Romero et al. 2019).

The rates of human–bear conflicts are increasing in response to human population growth, changes in land use, increasing livestock and crops, and the declining of the most common dietary items within their natural habitats (Jorgenson and Sandoval 2005). The bear may find food resources much easier inside farms than in the fragments of natural forest (Jorgenson and Sandoval 2005); such phenomena can be increased by its large food requirements and wide-ranging behavior (Paisley 2001, Jorgenson and Sandoval 2005). As more bears raid crops and enter farms and settlements, the lack of any bear protection status of many areas may result in the retaliatory killing of bears (Sánchez-Mercado et al. 2008, García-Rangel 2012, Figueroa 2015, Velez-Liendo and García-Rangel 2017).

Retaliatory killing is a serious threat throughout the species' range due to their occasional feeding on crops or killing livestock (Figueroa 2015). Better information is needed regarding the magnitude of crop damage, ecological integrity, food resources of the natural habitats around the affected farms, and the possible routes of dispersion (from and toward the affected farms) with the aim of identifying solutions to prevent and/or mitigate human–bear conflicts (Treves and Karanth 2003). It is also important to understand the attitudes of the affected farmers toward the species (Paisley 2001). Negative attitudes toward bears can increase retaliatory killing and the rejection of any conservation efforts inside or around protected areas (Jorgenson and Sandoval 2005). Given that retaliatory killing may be a consequence of mismanagement of the conflicts, the most desired consequence of management approaches to mitigate human–bear conflicts should also contribute to changing negative attitudes toward the species (Figueroa 2015). Effective mitigation strategies should consist of a series of actions that lead to improvement of the farmer's productive systems as well as create the conditions for internalizing the idea of Andean bear conservation (Marchini 2014).

In this study, we defined attitudes as mental structures formed by continuous interaction with an attitude object, which compose a roadmap for a response when faced with the same

Figure 2. Geographical range of the Andean bear (*Tremarctos ornatus*). Range taken from Velez-Liendo and García-Rangel (2017).

or similar attitude object in the future (Eriksson et al. 2015). The assessment of such attitudes is essential to monitor the efficacy of intervention efforts, and thus, drive them in the right direction (Thorn et al. 2012). Furthermore, stakeholders' heterogeneity must be understood to ensure that practice and policy interventions encompass the full range of stakeholder contexts and needs (Eriksson et al. 2015).

The purpose of our research was to describe human–bear conflicts within the Barbas-Bremen Soil Conservation District (SCD) protected area in the central mountain range of Colombia. Specifically, we describe feeding behavior of the Andean bear on plantain (*Musa sapientum*) and banana (*M. paradisiaca*) crops, the magnitude of crop damage and economic losses, distribution and hotspots of feeding sites and the attitudes of the affected farmers toward Andean bears.

Study area

Among the 12 management categories of protected areas in Colombia, the SCD is a passive protected area, predominantly composed of private properties, integrated within the regional-level protected areas systems (National Council for Economic and Social Policy of Colombia [CONPES] 2010). This category allows the development of sustainable agricultural activities on private farms within the SCD (CONPES 2010). The Barbas-Bremen SCD (Figure 3) comprises an area of ~9,600 ha, from 1,600–2,600 m, located on the western slopes of the central Andean range of Colombia between Risaralda and Quindío departments (Gómez-Hoyos et al. 2014). Those departments are part of what is known as the Colombian coffee axis (Eje Cafetero), where the greatest quantity of Colombian coffee (*Coffea arabica*) is produced. Risaralda has an extension of 4,038 km^2 and a human population of 998,162 persons, and Quindío has an extension of 1,730 km2 and a human population of 571,733 persons (Colombian Government Open Data 2020). The human population that inhabits Barbas-Bremen SCD consists of 1,000 inhabitants (Regional Autonomous Corporation of Quindío 2014), which corresponds to 1.3% of the total human population living in the rural perimeter of Pereira, the capital city of the department of Risaralda (Municipal Environmental Management System 2002). The Barbas-Bremen SCD includes some fragments of sub-Andean and Andean forest as well as a matrix of agricultural lands consisting of coffee and banana crops and pastures for cattle (*Bos taurus*) production (Gómez-Hoyos et al. 2014). The study area has a mean annual temperature of 17–24° C and a bimodal pattern of precipitation ranging from 1,000–3,000 mm, with a dry season from July to August and a wet season from March to May and October to December (Gómez-Hoyos et al. 2014).

The Barbas-Bremen SCD is an essential component of interconnected protected areas of the central Andean range of Colombia, which have an extension of 140,841 ha and 11 protected areas (Figure 3). This block of interconnected protected areas is also among the most important regions for Andean bear conservation because it facilitates the dispersal of individuals through the north and south of the central mountain range of Colombia (Ministry of Environment and Sustainable Development 2001).

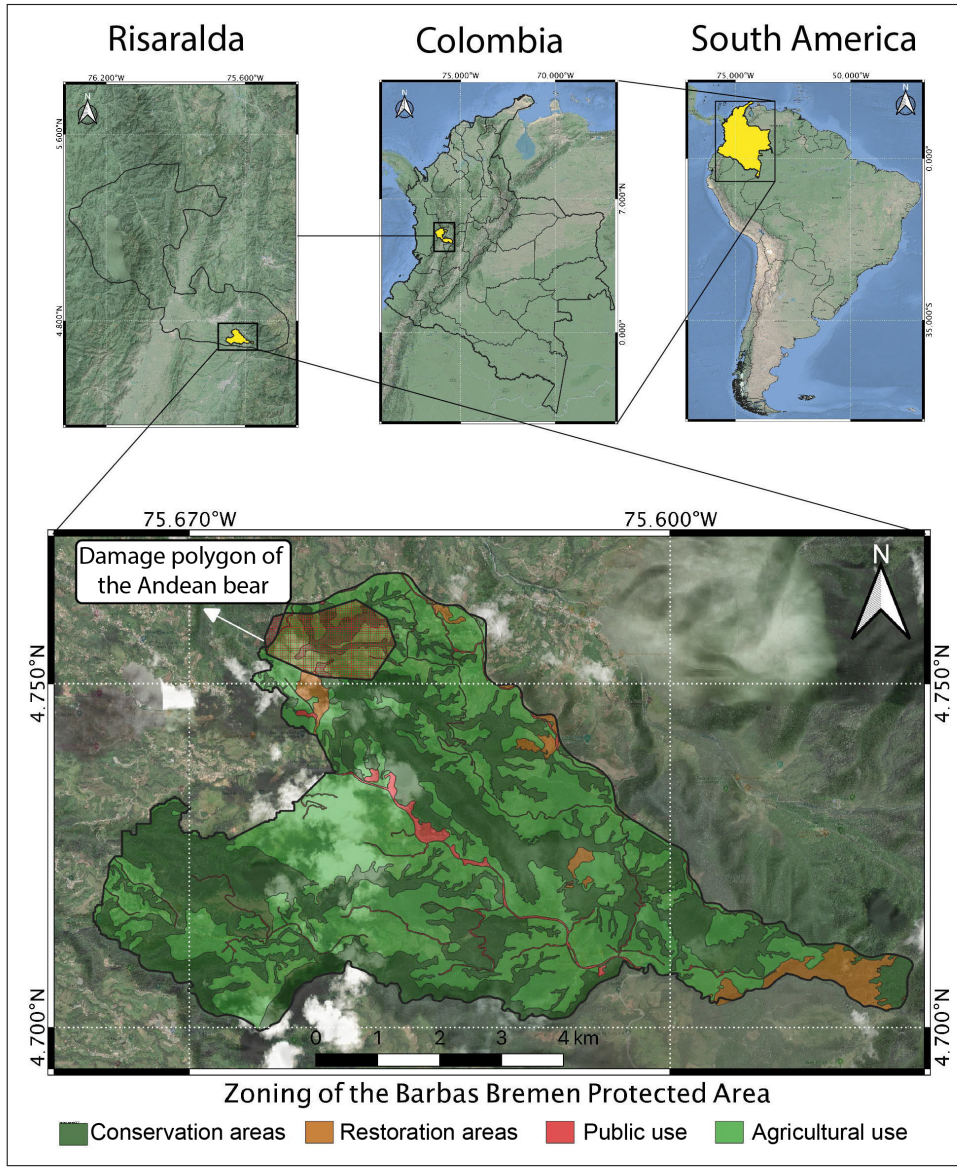

Figure 3. Geographic location of the Barbas-Bremen Soil Conservation District (SCD), Risaralda department, Colombia, in which Andean bears (*Tremarctos ornatus*) were reported feeding on banana (*Musa paradisiaca*) and plantain (*M. sapientum*) crops between April 6 and May 24, 2017. This protected area has the category of SCD, which is not a strict category of conservation; it allows the development of sustainable agricultural activities based on the zoning of the permitted land uses.

Methods

Our study was motivated by farmers' complaints concerning bear damage to banana and plantain crops at La Estrella-Morron Village (Pereira municipality), to the environmental authority of Risaralda department, the Corporación Autónoma Regional de Risaralda (CARDER). Between April 6 and May 24, 2017, we visited banana and plantain crops near La Estrella-Morron village to assess the magnitude of damage and corroborate the species that caused it. We follow the methodology described by Torres (2006). The damage variables we recorded included excrement, scratched trees, trails, feeding site, and footprints. We also interviewed 5 farmers who had witnessed bears feeding on plantain and banana plants to refine our assessment.

Table 1. Total number of plants, number and percentage of damaged plants, and economic losses of farms with damaged crops of plantains (*Musa sapientum*; *M.s.*) and bananas (*M. paradisiaca*; *M.p.*) by Andean bears (*Tremarctos ornatus*) inside of the Barbas-Bremen protected area, Risaralda, Colombia, April 5, 2017.

#	Farm name	Farm area (ha)	Total plants			# Damaged plants (%)			Economic losses (USD)		
			M.s.	*M.p.*	Total	*M.s.*	*M.p.*	Total	*M.s.*	*M.p.*	Total
1	El Edén	2	438	162	600	17 (3.8)	0 (0)	17 (2.8)	67.66	0	67.66
2	La Campiña	3	200	50	250	35 (17.5)	0 (0)	35 (10)	139.3	0	139.3
3	La Sonia	4	2,813	687	3,500	2 (0.07)	0 (0)	2 (0.05)	7.96	0	7.96
4	El Silencio	2.5	4,579	421	5,000	7 (0.15)	8 (1.9)	15 (0.3)	27.87	47.84	75.71
5	El Bosque	5.5	1,824	876	2,700	64 (3.5)	11 (1.2)	75 (2.7)	254.72	65.68	320.4
6	Los Rosales	5	505	995	1,500	16 (3.1)	9 (0.9)	25 (1.6)	63.68	53.82	117.5
7	El Topacio	5	1,528	472	2,000	15 (0.98)	5 (1)	20 (1)	59.7	29.9	89.6
8	La Lira	10	7,530	1,470	9,000	31 (0.41)	14 (0.95)	45 (0.5)	123.38	55.72	179.1
9	Parnaso	4	2,300	0	2,300	3 (0.13)	0 (0)	3 (0.1)	11.94	0	11.94

Feeding behavior and crop damage

We recorded how, when, where, and how many of the banana and plantain plants were consumed by Andean bears. For damaged plants, we also documented date, time, coordinates, photographs of the damage, affected crop species, and a written description of the damage.

To calculate the magnitude of the damage caused by Andean bears, we recorded the total number of banana and plantain plants on the property, total number of damaged plants (in both cases the percentage of damage was estimated), and the economic losses caused by the species. We estimated total economic losses for each farm based on the current cluster price of plantains and bananas in the local markets ($3.98 and $5.98 USD per cluster, respectively). We recorded this price on June 6, 2017 in a local market of the city of Pereira.

To obtain global economic losses for each farm, we multiplied the cluster price by the number of damaged plants on each farm. One plant loss corresponds only to 1 cluster loss because these plants are monocyclic and have only 1 fructification across their entire life cycle. Also, it is important to highlight that the local price of a cluster can vary with time depending of the supply-demand of clusters in the local markets.

Distribution and hotspots

We assessed the distribution and hotspots of bear feeding areas on plantain and banana crops through diurnal surveys. During these surveys, we recorded all plants damaged by bears, including crop species and the geographic location. To avoid duplication of damaged plants, we marked every plant with red paint once its location was recorded. We mapped the distribution and estimated hotspots of crop-feeding areas and their size using the plugin Heatspots and measuring areas available with QGIS software (version 2.18.14). We calculated the damage polygon by estimating the area (ha) of the minimum convex polygon of the extreme locations of damaged plants or feeding areas inside the agricultural lands of Barbas-Bremen SCD.

Farmer attitudes

During the visits to the affected farms, we also interviewed all farmers affected by Andean bears using structured interviews. We developed the questions prior to the interview, and

Figure 4. Banana (*Musa paradisiaca*) and plantain (*M. sapientum*) crops consumed by the Andean bear (*Tremarctos ornatus*) within the Barbas-Bremen protected area, Risaralda, Colombia (A–E). The Andean bear bit the banana tree base and consumed the pith of the trunk. Bites and claw marks are shown on the trunk of the plantain tree (F; *photos courtesy of S. Escobar-Lasso, taken between April 6 and May 24, 2017*).

the data collection was completed by an interviewer rather than through a self-administered questionnaire. The questions are standardized, and their ordering and phrasing are kept consistent. This interview was designed by the Wildlife Conservation Society Colombia (WCS) and then adapted by the environmental authority of the department of Risaralda, CARDER. The main administrators of the affected farms answered the questions, and in some cases, family members also provided input.

The structured questionnaires were divided into 6 parts: (1) respondent demographics, (2) farm features, (3) farm agriculture, (4) livestock management and crop farming, (5) damage caused by bears, and (6) attitudes toward Andean bears. We divided this last part (attitudes) into 3 categories: attitudes toward bears, attitudes toward institutions associated with bear conservation, and preventive measures.

We did the first round of interviews a few days after the damages occurred (between April and May 2017). Ten months after the initial interviews (between February and March 2018), we completed a second round of interviews to all affected farmers to assess the effect of the time from damage on their attitudes. We sought to identify all farmers who experienced bear damage to their crops. To accomplish this, community members convened a meeting to inform the farmers of the research. Therefore, we assumed that 100% of the farmers affected by bears were interviewed.

To analyze farmer attitudes, we classified each response as positive, negative, indifferent, or unanswered. We used the percentage of each category to describe the attitudes of the affected farmers. Finally, we compared the attitudes among the first and second rounds of interviews.

Results

Feeding behavior and crop damage

Nine farms in the study area were affected by bear damage (Table 1). The main crops of the farms consisted of plantain, banana, and coffee, with small crops of yuca (*Manihot esculenta*), tomatoes (*Solanum* spp.), and onions (*Allium fistulosum*). In our study, bears only consumed plantain and banana crops (Figure 4). This was likely because of the low availability of other crop types in the region. The bears

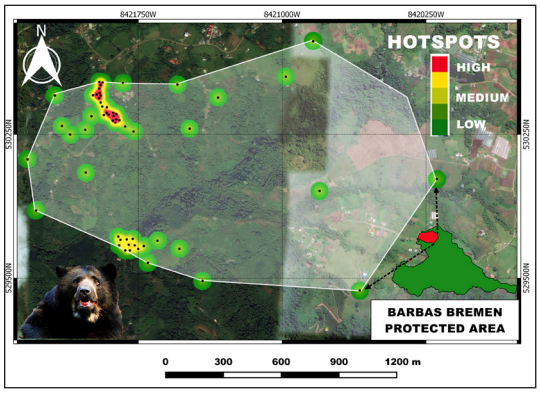

Figure 5. Distribution and hotspots of feeding areas of the Andean bear (*Tremarctos ornatus*) on plantain (*Musa sapientum*) and banana (*M. paradisiaca*) crops and the damage inside the agricultural lands of Barbas-Bremen protected area, Risaralda, Colombia, April 6 to May 24, 2017.

Figure 6. Sub-Andean forest of the Consotá River, which is located near the sites of plantain (*Musa sapientum*) and banana (*M. paradisiaca*) crop damage caused by Andean bear (*Tremarctos ornatus*) within the Barbas-Bremen protected area, Risaralda, Colombia, April 5, 2017.

bit plantain trunks at a height of 0.96 ± 0.27 m (0.32–1.4 m) and bananas at a height of 0.77 ± 0.25 m (0.5–1.1 m), which caused the plants to fall. Then, individuals consumed the heart of the trunks and, curiously, never consumed the clusters. The farmers reported that all damage occurred at night.

We surveyed 21,717 plantain plants and 5,133 banana plants between April 6 and May 24, 2017 (Table 1). We documented damage to 237 (0.88%) plants (Table 1). Of these, 190 plants (0.87%) were plantain and 47 (0.91%) plants were banana (Table 1). For all farms, we estimated a total economic production profit, related to *Musa* spp. crops, of $117,129 USD: $86,433.66 USD for plantains and $30,695.34 USD for bananas. We estimated the economic losses attributed to bear damage as $1,009.10 USD (0.86%): $756.20 USD for plantains (0.87%), and $252.90 USD for bananas (0.82%).

Distribution and hotspots

We recorded 57 feeding area locations (Figure 5). The damage polygon inside the agricultural lands of Barbas-Bremen SCD encompassed 198 ha and was located in the northwestern part of the protected area (Figure 5). We found 2 major hotspots of crop feeding sites within the study area located on the southwest and northwest extremes of the damage polygon. The northwest hotspot was slightly larger (18 feeding area locations; 18,738 m^2) compared with the southwest hotspot (11 feeding area locations; 15,250 m^2). Both hotspots are located between a remnant of native forest adjacent to the Consotá River (Figure 6).

Farmer attitudes

The economy of the 9 affected farm families is 100% based on the production of plantains, bananas, and coffee. The families of all interviewees live on the same land where the crops are located. The crops were all protected by 2-wire fencing to restrict livestock. However, the fencing did not prevent bears from entering the crops.

During the first round of interviews conducted a few days after the damages, 81.5% of all answers were negative (Figure 7A). These farmers agreed to quotes categorized as negative, such as "bears cause damage on the croplands." Similarly, all 9 farmers answered that their friends did not want the bears to be around. On the other hand, positive answers composed 18.5% of all answers. Only 2 farmers did not agree with being worried about the presence of the bear. Unexpectedly, they answered that bears were not hunted in the locality and they disclaim if any person has tried to hunt an Andean bear around their farms.

In the second round of interviews, 10 months later, 85.2% of the answers were negative (Figure 7B). The percentage of positive answers was reduced to 14.8%. Farmers' perceptions of conservation organizations differed between the first and the second round of interviews. On the first round, 60% of the answers reported positive attitudes toward institutions, whereas 33% of the answers were negative. However, in the

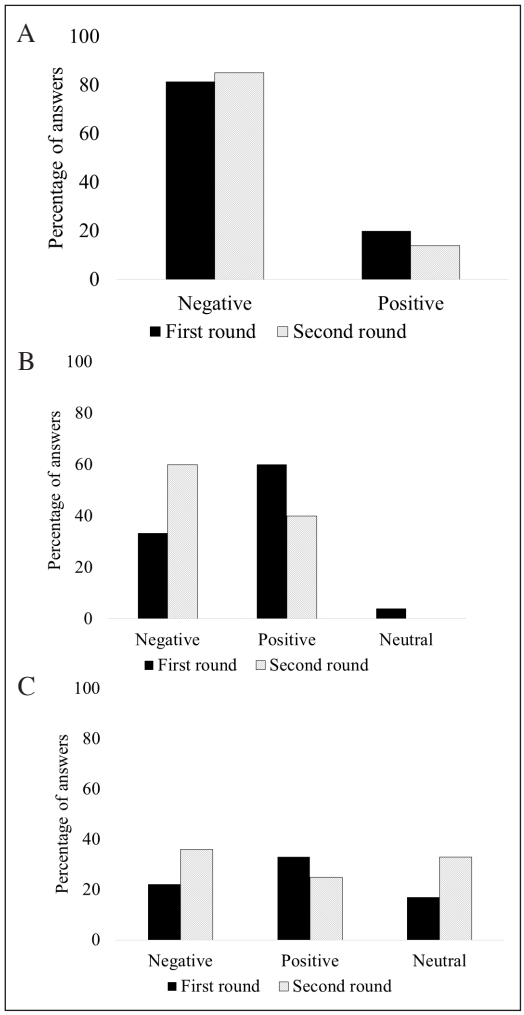

Figure 7. Attitude of affected farmers toward Andean bears (*Tremarctos ornatus*), institutions, and preventive measures in the agricultural lands of Barbas Bremen protected area, Risaralda, Colombia. Dimensions of the attitudes were compared between rounds of interviews: (A) attitudes toward the bears, (B) attitudes toward institutions, and (C) attitudes toward preventive measures. The first round of interviews occurred few days after the damage to crops (between April and May 2017); the second round was carried out 10 months later (between February and March 2018).

second round, 60% of the answers were negative and 40% were positive. All the interviewed farmers in both rounds of interviews think that the Colombian Government must be responsible for the mitigation of bear conflict events.

In 33.3% of the answers from the first round of interviews, farmers agreed with positive phrases about the implementation of preventive measures in their farms (Figure 7C). In total, 22.2% of the answers about preventive measures were negative, and 16.7% were neutral. In 27.7% of the cases, the questions regarding preventive measures were not answered. In the second round, farmers' positive answers decreased to 25%. The number of farmers who had neutral attitudes toward implementation of measures increased from 16.7% to 33.3% between interview rounds. Also, the number of negative answers increased to 36% in the second round. This can be related to the fact that prevention is not a static behavior; it requires maintenance and constant monitoring.

Discussion

Feeding behavior and crop damage

Andean bears have been recorded feeding on 26 different types of crops throughout their distribution range, and 27 scientific papers have reported the consumption (Table 2). Andean bears have already been recorded eating banana fruits and piths in Venezuela, Ecuador, and Bolivia, as well as plantain crops in Colombia and Venezuela (Table 2). However, our work is the first to describe banana crop consumption in Colombia and is also the first detailed description of the species' feeding behavior on bananas and plantains throughout its distribution range.

Andean bears have diurnal habits, and previous studies about crop consumptions usually occurred during daytime (Herrera et al. 1994, Castellanos 2010, Figueroa et al. 2013, Figueroa 2015). We were not able to determine the exact time when crop damages occurred, but according to surveyed farmers, the damage occurred at night. There is a possibility that crop consumption could have happened at sunset and sunrise. Parra-Romero et al. (2019) found that in a highly fragmented and densely populated area of the Chingaza Massif, central Colombia, scavenging behaviors of the species occurred early at sunrise.

In our study area, we believe that the bears were exhibiting non-diurnal feeding behavior because of the high fragmentation of natural forests, density of humans in the area, and number of people moving through agricultural areas during the day. We were not able to record the number, sex, or age of the individuals involved on crop damage. However, some empirical background suggests that males are more inclined to feed on human crops (Figueroa

Table 2. Crops recorded on the diet of the Andean bear (*Tremarctos ornatus*) throughout its distributional range.

Species	Venezuela	Colombia	Ecuador	Peru	Bolivia	Argentina	References[a]
Agave americana				X			5
Ananas comosus			X	X			1, 2, 3, 4, 5, 10
Annona cherimola				X			1, 2, 3, 4, 23, 24
Arracacia xanthorrhiza				X			2, 3
Opuntia ficus-indica				X			1, 2, 3, 18
Carica papaya			X				5
Cucurbita pepo				X			1, 2, 4, 5
Cucurbita maxima				X			1, 2, 4, 5, 24
Cucurbita moschata				X			1, 2
Citrus sp.					X		1, 2, 19
Guadua sp.					X		5, 15, 24, 25
Lucuma ovata				X			1, 2, 4, 5
Manihot esculenta				X			1, 2
Persea americana			X	X			1, 2, 3, 5, 8
Musa paradisiaca	X	X	X	X	X		1, 2, 5, 7, 9, 27
Musa sapientum	X	X				X	1, 2, 5, 26, 27
Phaseolus vulgaris		X					6
Psidium guajava	X		X	X	X		1, 2, 4, 5, 7, 8, 9
Saccharum officinarum	X	X	X	X	X		1, 2, 3, 4, 5, 7, 8, 9, 13, 21, 22, 23, 24
Zea mays	X	X	X	X	X	X	1, 2, 4, 5, 6, 8, 10, 11, 12, 13, 15, 16, 17, 18, 20, 22, 24, 25, 26
Pouteria lucuma				X			5
Rubus sp.	X				X		4, 5, 8, 14, 15
Passiflora ligularis			X				5
Solanum betaceum			X				5
Solanum quitoense			X				1, 2, 5, 10
Solanum tuberosum	X	X		X			1, 2, 3, 7, 22

[a] (1) Figueroa 2013*a*; (2) Figueroa 2015; (3) Figueroa and Stucchi 2013; (4) Figueroa 2013*b*; (5) Castellanos et al. 2016; (6) Robles and Gómez-Carrillo 2017; (7) Herrera et al. 1994; (8) Torres 2006; (9) Castellanos et al. 2005; (10) Castellanos 2010; (11) Bazantes et al. 2018; (12) Albarracín 2010; (13) Morales 2003; (14) Ríos-Uzeda et al. 2009; (15) Albarracín et al. 2013; (16) Butchart et al. 1995; (17) Tschudi 2003; (18) Baiker and Collatupa 2011; (19) Yañez and Eulert 1996; (20) Rumiz et al. 1999; (21) Paisley 2001; (22) Ojeda and Pesca 2006; (23) Benjarano-Romero 1999; (24) Peyton 1980; (25) Mondolfi 1989; (26) Rodríguez et al. 2019; (27) This study.

2015), mainly because they have larger movement ranges than females, which translates into greater energy expenditure and therefore appetite (Castellanos et al. 2005). However, females with cubs can also cause important crop damages (Castellanos et al. 2005, Figueroa 2015).

Crop consumption is a common phenomenon in other bear species around the world (Ditmer et al. 2015*a*, *b*). In Nearctic regions, where the food abundance is limited by climate seasonality, bears have greater food requirements given the need for accumulating fat for hibernation, which causes a state of hyperphagia (Hilderbrand et al. 1999). During hyperphagia, the possibility of bears invading crops, farms, and settlements increases, usually generating human–bear conflicts. This sort of conflict has been reported on brown bear (*U. arctos*; Blanchard and Knight 1991, Sato and Endo 2006), and American black bear (*U. americanus*; Garshelis et al. 1999; Ditmer et al. 2015*a*, *b*) feeding on crops such as corn, oats (*Avena sativa*), soybeans (*Glycine max*), wheat (*Triticum* spp.), and sunflowers (*Helanthus annuus*).

In tropical regions, where there are usually constant food resources, the increase in human–bear conflict is probably explained by habitat loss, fragmentation, and agricultural expansion (Fredriksson 2005, Liu et al. 2011). This has been reported for other tropical bears, such as the sloth bear (*M. ursinus*), Asiatic black bear (*U. thibetanus*), and sun bear (*Helarctos malayanus*; (Malcom et al. 2014, Singh et al. 2018). Therefore, it is likely that habitat loss, fragmentation, and agricultural encroachment are pushing Andean bears to feed more on crops in our study area.

Crop damage and economic losses

In our study, crop damage and economic losses were relatively incipient and did not represent a real threat to the stability of banana and plantain crops in the region. Moreover, the cases presented here are the only known in the area, which leads us to think that this human–bear interaction is still rare in the area.

There are no studies that analyze the economic losses caused by the bears to crops (Figueroa 2013*a*), making it difficult to establish comparisons with other regions. Therefore, this work could be considered the first attempt to quantify economic losses caused by Andean bears throughout its distribution range. Apparently, Andean bears cause minimum economic losses compared to other species; for instance, Asiatic black bears in Nepal can feed on 3,818 kg of corn crops annually, generating economic losses of $2,235 USD (Chhetri 2013). However, we pointed out that a more representative sample of crop raiding events caused by the Andean bear in the area is needed to have a more robust assessment of the economic dimension of the conflict. In addition, more farms of both small and large producers around study areas involving human–bear conflicts must be included to deploy robust comparisons of economic losses in different spatial and temporal scales (Garshelis et al. 1999). To design effective conservation programs aimed to economically compensate affected farmers, it is essential to understand the actual economic magnitude of the damages and to monitor the extent of the damages over time (Karamanlidis et al. 2011).

Distribution and hotspots

The Consotá River Basin is one of the latest remnants of native forest that could be acting either as a dispersal corridor for Andean bear populations, enabling individuals to move inside and outside of the agricultural landscape, or as a temporal refuge to avoid encounters with domestic dogs (*Canis lupus familiaris*) and people. The use of remnant forests to access farmlands has been observed in other bear species (Peyton 1981, Clark et al. 2005, Malcom et al. 2014); unfortunately, the underlying reasons that could explain our hotspots remain unknown. However, it is important to highlight that the damage polygon was located 2.8 km from the city of Pereira (the largest city in the area), an atypical location given the strong evidence that suggests that Andean bears avoid urban areas (García-Rangel 2012).

To our knowledge, our research is the first to confirm the presence of Andean bears inside the Barbas-Bremen SCD protected area, thus highlighting the importance of the records, but also of the conflict situations in the area. The Barbas-Bremen SCD is part of an important block of 11 interconnected protected areas that have a total extension of 140,841 ha (Figure 8); of these, Los Nevados National Natural Park (NNP) is the only area with a potentially stable population of the species. Of these 11

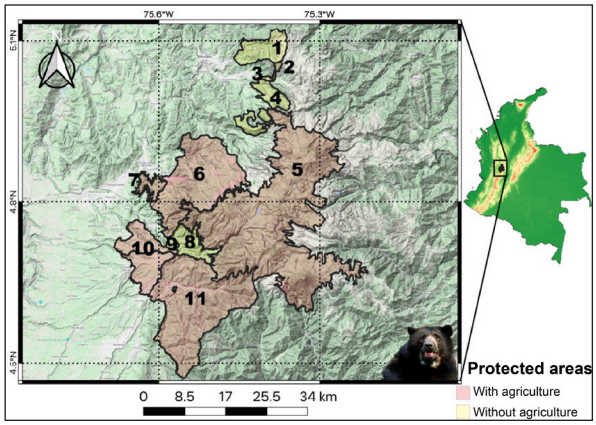

Figure 8. Area with reported damage by Andean bear (*Tremarctos ornatus*) to plantain (*Musa sapientum*) and banana (*M. paradisiaca*) crops within Barbas-Bremen Soil Conservation District (SCD) in the context of the protected area network in the region, Colombia. Black polygons are protected areas with prohibited agricultural activities: (1) Río Blanco Forest Protection Reserve (FPR) and Quebrada Olivares, (2) Torre Cuatro FPR, (3) Sabinas FPR, (4) Bosques de la Chec FPR, (5) Los Nevados National Natural Park, (8) Ucumari Regional Natural Park, and (9) Otún Quimbaya Sanctuary of Flora and Fauna. White polygons are protected areas with agricultural activities allowed: (6) Campoalegre SCD, (7) La Marcada SCD, (10) Barbas-Bremen SCD, and (11) Cuenca Alta del Río Quindío-Salento Regional Management District.

areas, 5 include mild to intensive farming: Barbas-Bremen SCD, Campoalegre SCD, La Marcada SCD, Cuenca Alta del Río Quindío-Salento Regional Management District, and Los Nevados NNP. Although farming is not legally allowed within Los Nevados NNP—a national system protected area—the large proportion of land is still under private property regimes (not yet purchased by the nation), which allows several agricultural activities such as cattle ranching and potato (*Solanum tuberosum*) production to still occur in the area. This reality further highlights the importance of understanding human–bear conflicts and the design and implementation of mitigation programs in the area.

The future existence of wild Andean bears depends on limiting human pressure on the species and its habitat (García-Rangel 2012). This is especially true for Colombia, where most human activities are concentrated throughout the distribution of the species; natural cover areas at high and mid-elevations in the Colombian Andes, where the species occurs, are also the sites of more intensive economic development in the country (Rodríguez-Castro et al. 2015).

Farmer attitudes

In Colombia, human–bear interactions can increase due to deforestation and human population increase (Jorgenson and Sandoval 2005). Negative perceptions of the Andean bear have been previously documented at the central mountain range (Parra-Colorado et al. 2014); thus, the environmental authorities should adequately address affected farmers as well as work intensively with the involved community to promote positive attitudes toward the species. Although crop damage and economic losses in our study were incipient, it seems such events have a disproportionate effect on negative attitudes and perceptions, even turning into persecution, toward Andean bears.

The farmers we surveyed indicated that they and most surrounding people did not want bears roaming the area. This could represent a social norm, defined as the perceived expectations of others' values, which also includes general expectations of behavior (Mengak et al. 2019). Most of the farmers were worried about the presence of bears given the perceived expected continued losses; although all farmers indicated that bears are not actively hunted in the region, considering that poaching is illegal in the country, these activities could be concealed. There was no clear influence of the time elapsed since the damage occurred in the attitudes toward bears. Regarding the attitudes toward institutions, farmers in the second round agreed that institutions were not very useful, that they did not finish their job properly, and that they do not appropriately protect the species. It is important to mention that attitudes toward carnivores can also be influenced by the perception of institutions related to these species; when no proper management or attention to conflict is given by institutions, such negative responses toward carnivores are likely expected (Sjölander-Lindqvist et al. 2015).

In general, the farmers wanted all bear conflicts managed by governmental institutions. This assumption is supported by law (National code of renewable natural resources and environmental protection 1974), where it is stated that wildlife is property of the Colombian state. Therefore, the main responsibility for human–

wildlife conflict management in Colombia is with the state itself, through regional environmental authorities of each department (Regional Autonomous Corporations [CARs]), but also from the central administrative level Environmental Ministry (CONPES 2010). However, it is important to increase public awareness regarding Andean bear conservation, especially focused on increasing the tolerance toward the species and by providing long-term solutions to the conflict.

Despite our small sample size, we accounted for the total number of affected farms during our sampling period. Still, sample size could be considered a limitation to our study, and our conclusions are not based on statistical analyses; nevertheless, we consider that our descriptive approach supports the novelty of the information provided and can be useful for future reference and as a baseline for further study of Andean bear conflict throughout the range of the species.

Although a National Andean Bear Program officially exists for the country (Ministry of Environment and Sustainable Development 2001), it has been scarcely implemented. Rural communities continue to hunt in retaliation of "problem" bears, even in the absence of damage or overestimated perception of the magnitude of the problem as in our study, and habitat loss is still at the forefront of Andean bear conservation challenges (Rodríguez-Castro et al. 2015). Consequently, further research and implementation of conservation measures are warranted; this includes the continuous evaluation of conservation efforts and alternative preventive measures.

Management implications

At the regional level, environmental authorities (departments of Caldas [Corpocaldas], Quindío [Corporación Autónoma Regional del Quindío; CRQ], and Risaralda [CARDER]) and Parques Nacionales Naturales (National Parks Administration) could articulate effective management plans for the 11 interconnected protected areas (see Figure 8), highlighting Andean bear conservation actions, as the species is considered one of the conservation objects in the area (Regional Autonomous Corporation of Quindío 2014). Such articulation should aim to include conflict prevention and mitigation, along with effective measures to revert habitat loss and fragmentation. The CARDER and CRQ, the institutions in charge of the Barbas-Bremen SCD, could benefit from establishing a long-term education program to improve attitudes and perceptions toward Andean bears and other species, incorporating preventive conservation measures, and even improving the perception about such institutions themselves.

Although a management plan for Barbas-Bremen SCD was created, it has not been fully implemented, and the agricultural border continues to expand into areas that were selected for conservation and restoration activities, according to the proposed zoning (see Figure 3). Therefore, CARDER and CR
Q should reinforce such zoning and should include Andean bears in the management plan, in accordance with management plans of the other interconnected protected areas.

We further recommend that the main crops consumed by the species (see Table 2), should be regulated inside the 11 interconnected protected areas of the central mountain range, especially inside the 5 protected areas that allow agricultural activities inside their territory (see Figure 8). To do this, it is necessary for local environmental authorities and Parques Nacionales Naturales, which are the managers of those protected areas, to work closely and communicate with farmers who live within those areas.

Although we still do not fully understand the magnitude of Andean bear conflict in the entire region among other threats to the species, the available information, including our study, could likely inform and incentivize decision-makers to further research these phenomena at regional scales; such information, together with proactive and informed conservation measures, could significantly improve the status of the species and protected areas in general in one of the most biodiverse regions in the country.

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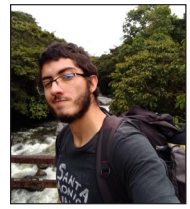

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