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Artículo

Human-wildlife conflicts in Latin America: A systematic review of jaguars (*Panthera onca*) and Andean bears (*Tremarctos ornatus*)

Conflictos entre humanos y vida silvestre en América Latina: una revisión sistemática sobre el jaguar (*Panthera onca*) y el oso andino (*Tremarctos ornatus*)

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Abstract

Forest cover in Latin America has decreased in recent years due to the expansion of agriculture, forestry, and livestock ranching, exacerbating human-wildlife conflicts (HWC). This study analyzes 22 articles about HWC in Latin America related to the jaguar (*Panthera onca*) and the Andean bear (*Tremarctos ornatus*), two symbolic species affected by hunting in retaliation for damage caused to livestock or crops. It identifies the countries, problems caused, and the strategies proposed or applied to resolve them, and determines their effectiveness. Ecuador was the country with the most publications. The most frequent problem for both species was attacks on livestock. The most common strategy applied by communities to manage the HWC was hunting and killing the animal, and the most common strategy proposed by the authors was conservation education. More research is needed on HWC in Latin America, especially on evaluating the effectiveness of strategies to manage them, to better understand the problem and implement effective management measures that prevent negative impacts on people and wildlife.

Keywords: big cats, crops, predation, HWC, livestock, spectacled bear.

Resumen

Los bosques en Latinoamérica han disminuido en los últimos años debido a la expansión de la agricultura, la silvicultura y la ganadería, exacerbando los conflictos entre humanos y la vida silvestre (HWC). Esta investigación analiza 22 artículos sobre HWC en Latinoamérica, relacionados con el jaguar (*Panthera onca*) y el oso andino (*Tremarctos ornatus*), dos especies representativas que han sido afectadas por la caza en represalia por los daños causados al ganado o a los cultivos. Se identificaron los países, problemas y estrategias propuestas y/o aplicadas para resolverlos, así como su efectividad. Ecuador fue el país con más publicaciones. El problema más frecuente para ambas especies fue ataques al ganado. La estrategia más común aplicada por las comunidades para gestionar el HWC fue la caza, y la estrategia más propuesta por los autores fue la educación para la conservación. Es necesario profundizar más sobre la evaluación de la efectividad de las estrategias para gestionar los HWC, para comprender mejor el problema e implementar medidas de manejo efectivas que prevengan impactos negativos en las personas y en la vida silvestre.

Palabras clave: cultivos, depredación, ganado, grandes felinos, HWC, oso de anteojos.

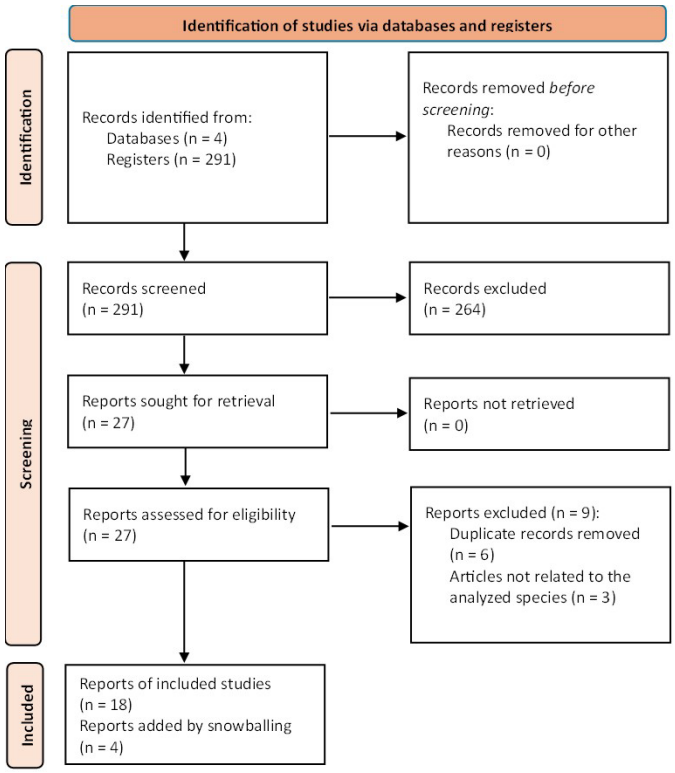
Introduction

As the world's population increases, animals and humans face a competition for limited resources (Ceballos et al., 2015; Margulies & Karanth, 2018). In this process, humans have expanded their settlements and agricultural areas to meet their needs. According to the Economic Commission for Latin America and the Caribbean from the United Nations (2021), in Latin America and the Caribbean, forest cover declined from 53% to 46% of its land area between 1990 and 2020, due to agriculture, forestry and livestock ranching (Ballejo et al., 2022; Debebe et al., 2023). This phenomenon has changed the interaction between humans and wildlife, causing human-wildlife conflicts (HWC) and disputes between different groups of people (Madden & McQuinn, 2014; FAO, 2015; Frank et al., 2019).

Wildlife can be seen as a threat to human wellbeing, especially in rural areas (Mekonen, 2020). This generates HWC (Braczkowski et al., 2023), a concept defined by the IUCN SSC Human-Wildlife Conflict & Coexistence Specialist Group as "struggles that emerge when the presence or behaviour of wildlife poses actual or perceived, direct and recurring threats to human interests or needs, leading to disagreements between groups of people and negative impacts on people and/or wildlife" (IUCN SSC HWCTF, 2023). HWC involve species such as big cats, elephants, primates, crocodilians, bears, rhinos, among others (IUCN SSC HWCTF, 2023), and are not new, as wildlife and people have coexisted for millennia (Dickman and Hazzah, 2016). However, they have become a global concern for conservation (Can et al., 2014; Marchini, 2014) efforts, including achieving sustainable solutions for damages caused by HWC, guaranteeing species survival, and protecting the livelihood of human populations.

Despite being two of the most iconic species of large mammals in Latin America, the jaguar (*Panthera onca*) and the Andean bear (*Tremarctos ornatus*) are being hunted by farmers or ranchers in retaliation for damages caused by them to livestock or crops (FAO, 2015; Hernández, 2016; Knox et al., 2019). The jaguar is categorized by the IUCN (2016a) as "Near Threatened", and, according to Zimmermann et al. (2005), conflict with humans often results in animal killings (Marchini & Macdonald, 2012), which is one of the main threats to this species in the region (Pooley et al., 2016). The Andean bear is the only ursid (bear) in South America (Peyton et al., 1999), and it is categorized as "Vulnerable" by the IUCN (2016b), due, mainly, to habitat loss, illegal hunting and human-bear conflicts (Can et al., 2014). In Latin America, crop and livestock farming are considered key economic activities for food security (Rodriguez et al., 2016). Therefore, it is important to find

Figure 1. PRISMA 2020 flow diagram for this systematic review.



Notes. Adapted from Page et al. (2021).

solutions to HWC related to livestock predation and damage to crops (Karanth et al., 2013), not only for economic benefits, but to prevent and control biodiversity loss.

Latin America has a significant volume of research on HWC, most of it aimed at conflicts between felines and other carnivores with livestock and agricultural production. Countries like Ecuador, however, have focused on issues related to the Andean bear (Iñiguez-Gallardo et al., 2021). To further our understanding of HWC involving these two species, the jaguar and the Andean bear, this study reviews Latin American scientific articles on the topic and aims to: 1) determine the countries where research projects were conducted, 2) identify the type and extent of the problems caused by each species, 3) recognize problems common to both species, 4) identify the proposed and/or applied strategies to solve said problems, 5) establish whether there are common strategies to deal with the problems, and 6) determine the effectiveness of the proposed and/or applied strategies, in case they were assessed by the article.

Materials and methods

Sources of data collection

A systematic review of articles was conducted following the PRISMA 2020 Statement (Page et al., 2021) (Figure 1). The databases (Table 1) were consulted in "all fields" and filtered for articles or research articles. The same keywords and search strings were used in Scopus, Web of Science and Google Scholar: human-wildlife AND conflict AND ((Andean AND bear) OR jaguar OR (Tremarctos AND ornatus) OR (Panthera AND onca)) AND (Latin AND America). Science Direct did not allow too many Booleans connectors, so the keywords were modified to human-wildlife AND conflict AND ((Andean bear)

OR jaguar OR (Tremarctos ornatus) OR (Panthera onca)) AND (Latin America). Taking into consideration the geographical scope of the review, Google Scholar was also used as a source of articles in Spanish, since documents in this language were not found in the other databases.

Table 1. Filtering process for the selection of articles for topic review.

Database	Records screened	Articles assessed for eligibility	Articles included
Scopus	73	11	8
Science Direct	54	4	2
Web of Science	7	3	1
Google Scholar	157	9	7
Other			4
Total	291	27	22

The title and the abstract of each article were first screened on Scopus, then Science Direct, Web of Science, and finally on Google Scholar. Records directly related to the topic "Human- wildlife conflict in Latin America" with the species *Panthera onca* or *Tremarctos ornatus* were then selected for a deeper review (Table 1). After assessing the eligibility of 27 selected documents, 9 of them were excluded, as 3 articles on Scopus were not related to the analyzed species, and several were repeated across the databases: 2 articles from Scopus were also on Science Direct, 2 on Web of Science, and 2 more on Google Scholar. This first screening totaled 18 articles for review.

Lastly, 4 more articles related to the Andean bear were added by snowballing after checking the reference list of the articles included in the review, in order to get a more representative analysis. The final 22 articles (Appendix 1) were then saved in Zotero for management.

Review of sources and extraction of information

Each of the selected articles was reviewed in detail to extract information/variables related to HWC. This data was organized in an Excel using the following structure: title of the article, publication year, authors, country and study area of the research, species studied, identified conflict, quantification of the problem, strategies applied by communities to solve the problem, effectiveness of those strategies (if it was assessed), and strategies proposed by the authors to solve the problem. None of the articles established how to identify the effectiveness of the strategies. So, for the purposes of this systematic review, the effectiveness was defined as the "measure of the success in achieving a clearly stated objective" (McCormick, 1981), understanding the objective as the management of HWC assessed by the authors of the publications. Finally, frequency distributions were analyzed for identified variables.

Results

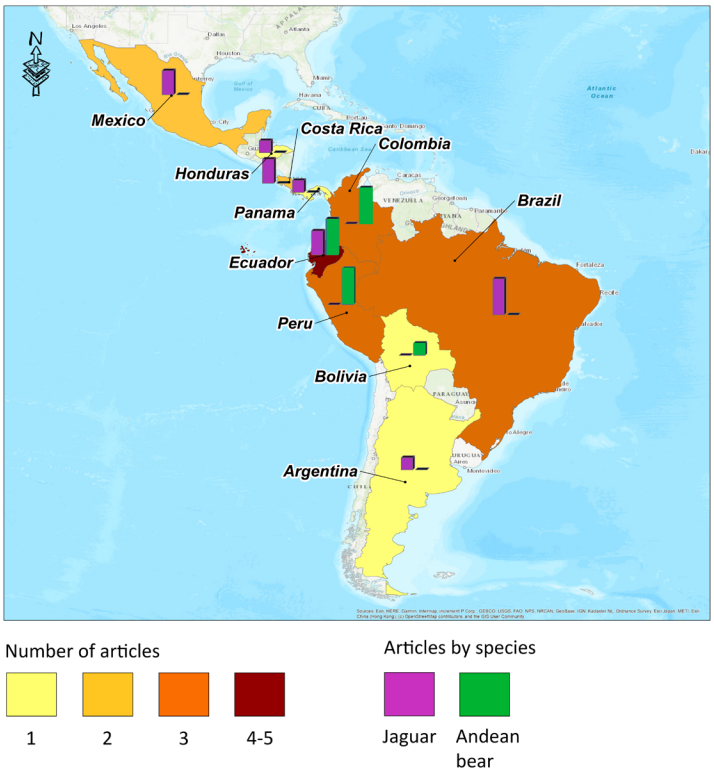
Geographic location

The articles cover research from 10 Latin American countries (Figure 2). The country with the most articles was Ecuador (5); followed by Brazil (3), Colombia (3), and Peru (3); then Mexico (2) and Costa Rica (2); and finally, Honduras (1), Panama (1), Bolivia (1), and Argentina (1). Of the analyzed publications, 12 (54.55%) corresponded to the jaguar (from Ecuador, Brazil, Mexico, Costa Rica, Honduras, Panama, and Argentina) and 10 (45.45%) to the Andean bear (from Ecuador, Colombia, Peru and Bolivia). The only country with research on both species was Ecuador (2 articles about the jaguar and 3 about the Andean bear).

Problem identification and quantification

Six main problems were associated to these species (Figure 3). The most common one was attacks on livestock. For the jaguar, this was mentioned in 9 of 12 articles, and for Andean bear, in 4 of 10 articles. Another common problem was attacks on humans. One article registered an attack on two people by an Andean bear between 2002-2008 (Figueroa, 2015) in Peru, and an article from Brazil described two nonfatal attacks on people from 2007-2010 and one fatal attack in 2008 (Campos et al., 2011). The Andean bear was

Figure 2. Countries in Latin America where HWC related to the jaguar and the Andean bear have been studied.



also connected to damage to plantations, while the jaguar was held responsible for attacks on domestic animals such as dogs. In one of the articles about Andean bears in Peru, the authors did not identify any problem, likely due to spatial segregation between bears and cattle (despite sharing elevation range).

The reviewed documents also presented quantities regarding killed animals, attacks (on livestock or humans), and plantations damaged, in different periods of time. The highest number of attacks on livestock by jaguars was reported in an article from Costa Rica: 280 attacks until 2014 (Amit & Jacobson, 2017), however, the authors claim that the attackers could have been pumas (*Puma concolor*). For the Andean bear, 250 attacks on cattle were reported from 2009 to 2012 in Ecuador (Jampel, 2016), but there is no information to determine whether they were carried out by one or several individuals. Finally, an article from Colombia registered damages to 190 plantain plants and 47 banana plants in 198 ha of land from April of 2017 to March of 2018 (Escobar et al., 2020).

Community strategies to manage HWC

The most common strategy used by communities to manage HWC was hunting or killing the animal (9 articles or 40.91% for jaguars and 4 articles or 18.18% for Andean bears) (Figure 4), followed by scaring it away (1 article or 4.54 % for jaguars and 2 articles or 9.09 % for Andean bears). Other less common strategies included the use of fences (both electric and non-electric) and permanent livestock supervision (1 article or 4.54 % of the total for the jaguars and 1 article or 4.54 % for the Andean bear). Some measures were found exclusively for the jaguar: night enclosures (2 articles or 9.09% of the total), stocks traps, poisoning, mutilation, guard animals, guard dogs, and grouping livestock close to human facilities (the six last were mentioned just in one article). Thirty-six percent of the articles (8) did not include information about community strategies to manage HWC.

Figure 3. Problems caused by the jaguar and the Andean bear identified in the selected articles.

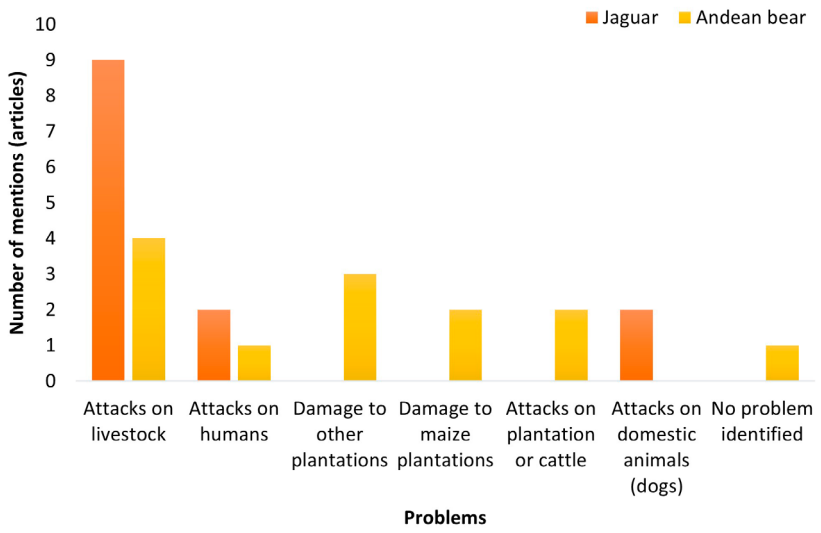


Figure 4. Strategies used by communities to manage HWC related to jaguars and Andean bears in Latin America.

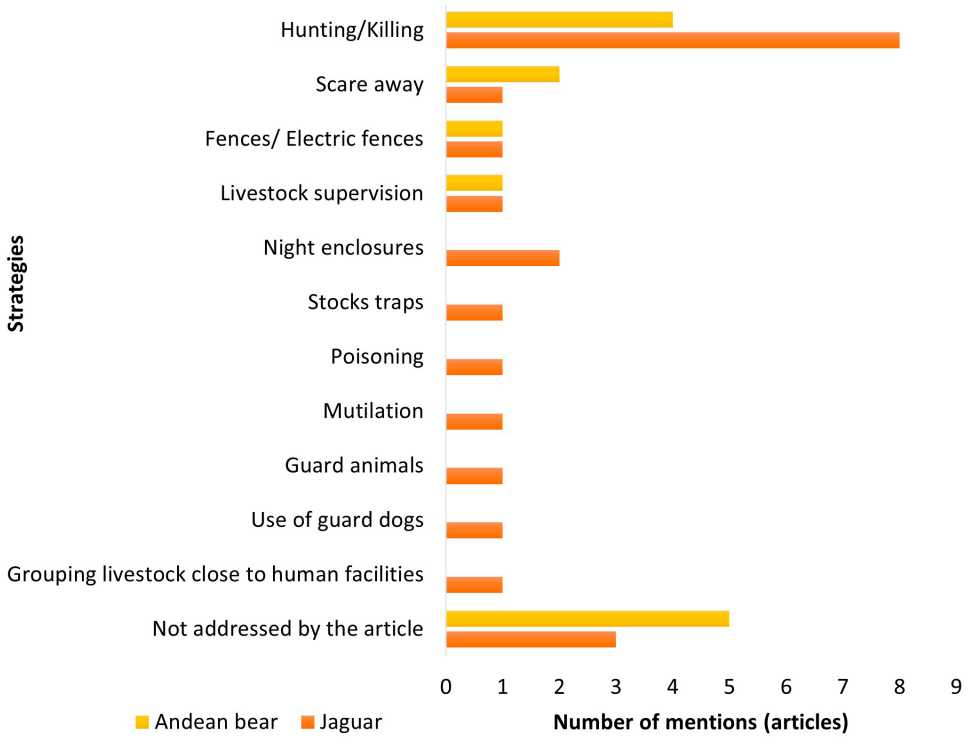
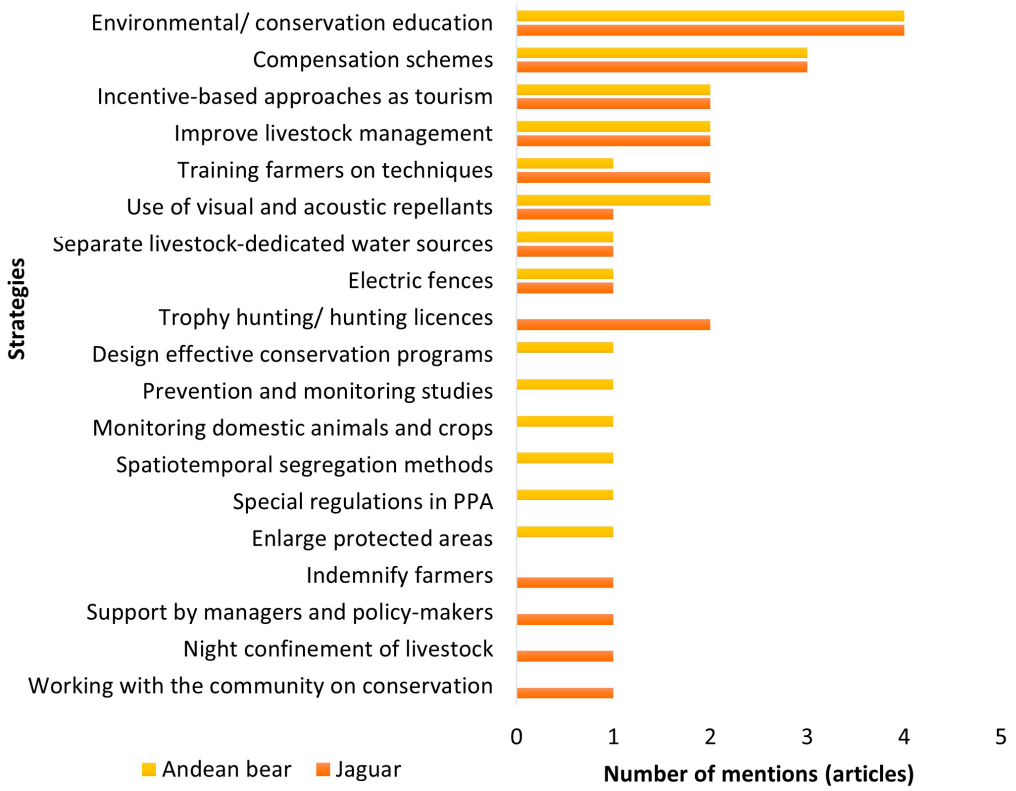


Figure 5. Strategies proposed by researchers to address the HWC related to jaguars and Andean bears in Latin America.



Author strategies to manage HWC

The most common strategy proposed by authors to manage HWC was environmental and conservation education, (four articles for each species), followed by the design of compensation schemes for farmers and ranchers (three articles for each species), and incentive-based approaches as tourism and improved livestock management (mentioned twice for each species). Less frequent strategies included training farmers on techniques to mitigate livestock predation, the use of visual and acoustic repellants, separated livestock-dedicated water sources, electric fences, among others.

Effectiveness of strategies to manage HWC

Only one article (4.55%) addressed the effectiveness of strategies used by communities to manage HWC. The authors analyzed the use of fences to protect crops from the Andean bear in Colombia, and determined that it is not an effective strategy. Although the plants were protected by 2-wire fencing to restrict livestock, bears were still able to enter and damage them (Escobar et al., 2020). The development of conservation programs (existing strategy) was also deemed ineffective. Despite the existence of a National Andean Bear Program in Colombia, its implementation by the government has been insufficient. This oversight has often resulted in retaliatory bear killings even in the absence of damage.

Two articles (9.09 %) assessed the effectiveness of strategies proposed by authors. One of them is mentioned above (Escobar et al., 2020). The other, related to the jaguar in Mexico, found that electric fences and night enclosures were effective strategies to avoid livestock predation, since the predation rate dropped significantly after the implementation of these measures (de la Torre et al., 2021). During the monitoring period (167 months), only one predation incident was registered (four sheep were killed by a

jaguar because the rancher did not enclose them). According to the authors, this indicates a high level of effectiveness of electric fences and night enclosures to prevent jaguar attacks on livestock.

One article assessed the theoretical effectiveness of a proposed strategy (i.e., non-existing) in Brazil. For the authors, the financial feasibility of a compensation scheme through wildlife tourism (Tortato et al., 2017) could be effective, since it would triplicate the estimated average land-use revenue, when compared to traditional cattle ranching across the Brazilian Pantanal. However, the authors suggested that it would be necessary to improve livestock management practices (e.g., the use of anti-predation methods) before developing a tourist-oriented compensation scheme.

Discussion

The data shows that while the jaguar is more researched regarding HWC in Latin America, the Andean bear is associated to a broader range of problems, specifically crop damage, as it is an omnivorous species (Figueroa, 2015; IUCN, 2016b). Both have a record of attacks on livestock and humans, a phenomenon that highlights the relevance of problem assessment with rural communities, education tools to understand environmental services and the importance of these two species (Zimmermann et al., 2005; Albarracín & Aliaga, 2018; Fort et al., 2018; Andrade et al., 2019; Caruso et al., 2020; Alvarez & Zapata-Rios, 2022; Macias & Vera, 2023), and the implementation of strategies to manage HWC. Furthermore, research has shown that the impact of education to reduce HWC is limited (Baruch et al., 2011). This is why the assessment of wildlife-related education programs should be a long-term endeavor (Espinosa & Jacobson, 2012) and focus on outcomes correlated to an increase or decrease in HWC, rather than measuring the delivery of education messages (Gore et al., 2006).

According to the analyzed literature, in Latin America people solve HWC using strategies that are within their reach to protect their economy and livelihoods. In total, eleven different strategies were identified. Some of them were used for both the jaguar and the Andean bear, such as scaring the animal away, fencing or permanent livestock supervision. However, hunting or killing the individual remains the most frequent solution for HWC, specially for jaguars (Sáenz et al., 2022). This could be explained by animal behavior. Big cats tend to be more violent than bears, which engenders in humans the fear of being attacked (Pooley et al., 2016; Sáenz et al., 2022). A study by Garrido-Corredor et al. (2021) presents a historical reconstruction of a similar problem for the Andean bear in Colombia.

HWC and retaliation killings are rooted not only in economic factors, but in sociocultural and historical backgrounds that include experience, culture, politics and identity. An effective solution to HWC therefore needs an interdisciplinary approach that considers the socioeconomic, ecological and cultural conditions under which these conflicts arise (Dickman, 2010; Marchini & MacDonald, 2012; Escobar et al., 2020; Zimmermann et al., 2021).

The reviewed documents propose a wide range of alternatives to deal with HWC. From 19 identified strategies, environmental and conservation education was the most common for both species. However, its effectiveness depends on the inclusion of human dimensions to understand and solve these kind of conflicts (Dickman, 2010; Marchini & MacDonald, 2012; Marchini, 2014; Figueroa, 2015; Escobar et al., 2020; Zimmermann et al., 2021; Painter et al., 2022). Other strategies include compensation schemes as compensatory solutions (Jampel, 2016; Caruso et al., 2020; Escobar et al., 2020). Preventive approaches that could diminish the occurrence of HWC remain an interesting yet unexplored topic, since the identified solutions are mainly based on mitigation, compensation or corrective strategies.

Most of the analyzed publications did not evaluate the effectiveness of community or proposed strategies (de la Torre et al., 2021), even when some of them were already being implemented in the study areas. This is the case of night penning of livestock,

enclosures, support by managers and policymakers, and economic compensations. Some articles, however, did highlight the effectiveness of certain measures. For example, the use of visual and acoustic repellants and electric fences against jaguars was considered effective in a study based in Mexico. After applying these techniques, the benefit-cost ratios ranged from 1.2 to 26.6, documenting efficient loss reduction without lethal control (Chinchilla, 2022).

Much research on the effectiveness of the strategies to deal with HWC in Latin America remains to be done. This is vital to better understand these conflicts and implement management solutions (such as non-lethal measures) that effectively avoid impacts on both people and wildlife. Among rural communities, killing and hunting are widespread practices that endanger the jaguar and the Andean bear. Therefore, working with them is key (Alvarez & Zapata, 2022) to address these issues appropriately.

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Appendix

Appendix 1. Summary of the literature on human-wildlife conflict, related to *Panthera onca* or *Tremarctos ornatus*.

#	Author(s)/ Year	Title	Species	Country	Study Area
1	Tortato et al., 2017	The numbers of the beast: Valuation of jaguar *(Panthera onca)* tourism and cattle depredation in the Brazilian Pantanal.	Jaguar *(Panthera onca)*	Brazil	Encontro das Aguas State Park and its surrounding landscape
2	Campos-Neto et al., 2011	Attacks by Jaguars (*Panthera onca*) on Humans in Central Brazil: Report of Three Cases, with Observation of a Death.	Jaguar *(Panthera onca)*	Brazil	Midwestern Brazil
3	Zimmermann et al., 2005	Cattle ranchers' attitudes to conflicts with jaguar *Panthera onca* in the Pantanal of Brazil.	Jaguar *(Panthera onca)*	Brazil	Administrative districts of Cáceres, Poconé and Barão de Melgaço in the Brazilian state of Mato Grosso
4	Sáenz-Bolaños et al., 2022	Human-wildlife conflict in indigenous communities of the Nairi Awari Indigenous Territory of East Central Costa Rica.	Jaguar *(Panthera onca)*	Costa Rica	Cabécar territory called Nairi Awari Indigenous Territory (NAIT)
5	Amit and Jacobson, 2017	Understanding rancher coexistence with jaguars and pumas: a typology for conservation practice.	Jaguar *(Panthera onca)*	Costa Rica	Costa Rica
6	Macias and Vera, 2023	Conflictos fauna silvestre-humanos en el área de influencia al Bosque Protector Cordillera Chongón Colonche.	Jaguar *(Panthera onca)*	Ecuador	Buffer area of Bosque Protector Cordillera Chongón Colonche
7	Alvarez & Zapata-Rios, 2022	Do social factors influence perceptions of the jaguar *Panthera onca* in Ecuador?	Jaguar *(Panthera onca)*	Ecuador	8 communities in the buffer area of two protected areas, El Pambilar Wildlife Refuge and Cotacachi-Cayapas Ecological Reserve
8	Painter et al., 2022	Land use change and its implications for biodiversity and jaguar conservation.	Jaguar *(Panthera onca)*	Mexico	Reserva de la Biosfera Sierra del Abra Tanchipa and a 10 km buffer of the surrounding landscape
9	de la Torre et al., 2021	A cost-effective approach to mitigate conflict between ranchers and large predators: A case study with jaguars in the Mayan Forest.	Jaguar *(Panthera onca)*	Mexico	Lacandona Rainforest in Mexico's state of Chiapas
10	Caruso et al., 2020	People and jaguars: new insights into the role of social factors in an old conflict.	Jaguar *(Panthera onca)*	Argentina	10 protected areas in northern Argentina
11	Chinchilla et al., 2022	Livestock–Carnivore Coexistence: Moving beyond Preventive Killing.	Jaguar *(Panthera onca)*	Honduras	Moskitia Hondureña
12	Fort et al., 2018	Factors influencing local attitudes and perceptions regarding jaguars *Panthera onca* and National Park conservation in Panama.	Jaguar *(Panthera onca)*	Panama	Cerro Hoya National Park and Darién National Park

#	Author(s)/ Year	Title	Species	Country	Study Area
13	Garrido-Corredor et al., 2021	Oso, Osito ¿A Qué Venís? Andean Bear Conflict, Conservation, and Campesinos in the Colombian Páramos.	Andean bear *(Tremarctos ornatus)*	Colombia	Páramos surrounding the capital city of Bogotá
14	Escobar-Lasso et al., 2020	Is the banana ripe? Andean bear–human conflict in a protected area of Colombia.	Andean bear *(Tremarctos ornatus)*	Colombia	Barbas-Bremen protected area in the central mountain range of Colombia
15	Robles and Gómez-Carrillo, 2017	Conflicto del oso andino *(Tremarctus ornatus)* con actividades antrópicas en Zetaquira- Boyacá.	Andean bear *(Tremarctos ornatus)*	Colombia	Zetaquira, Boyacá
16	Andrade et al., 2019	Percepción de actores clave acerca del conflicto ser humano-oso andino en la parroquia Plaza Gutiérrez, Íntag, Imbabura, Ecuador.	Andean bear *(Tremarctos ornatus)*	Ecuador	Parish Plaza Gutiérrez, valley of Íntag, province of Imbabura
17	Bazantes-Chamorro et al., 2018	Conflicto humano-oso andino *(Tremarctos ornatus)* en San Francisco de Sigsipamba, Provincia de Imbabura, Ecuador.	Andean bear *(Tremarctos ornatus)*	Ecuador	Parish San Francisco de Sigsipamba, province of Imbabura. North of Ecuador
18	Jampel, 2016	Cattle-based livelihoods, changes in the taskscape, and human–bear conflict in the Ecuadorian Andes.	Andean bear *(Tremarctos ornatus)*	Ecuador	Canton of Pimampiro, Ecuador
19	Aurich-Rodriguez et al., 2022	Threatened Andean bears are negatively affected by human disturbance and free-ranging cattle in a protected area in northwest Peru.	Andean bear *(Tremarctos ornatus)*	Peru	Laquipampa Wildlife Refuge, a protected area in northwest Peru
20	Rojas-VeraPinto et al., 2022	Living high and at risk: predicting Andean bear occurrence and conflicts with humans in southeastern Peru.	Andean bear *(Tremarctos ornatus)*	Peru	Southeastern Peru
21	Figueroa, 2015	Interacciones humano–oso andino *Tremarctos ornatus* en el Perú: consumo de cultivos y depredación de ganado.	Andean bear *(Tremarctos ornatus)*	Peru	Buffer areas of 16 protected areas in Peru
22	Albarracín & Aliaga-Rossel, 2018	Bearly Guilty: Understanding Human–Andean Bear Conflict Regarding Crop Losses.	Andean bear *(Tremarctos ornatus)*	Bolivia	Two indigenous Aymara communities, Chuñavi and Lambate, Bolivia