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EDITED BY
Jean Hugé,
Open University of the Netherlands, Netherlands

REVIEWED BY
Thomas Göttert,
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International Center for Biosaline Agriculture (ICBA), United Arab Emirates
Susanne Marieke Vogel,
Open University of the Netherlands, Netherlands

*CORRESPONDENCE
Roberta Montanheiro Paolino
paolinorm@alumni.usp.br

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Poaching and hunting, conflicts and health: human dimensions of wildlife conservation in the Brazilian Cerrado

Roberta Montanheiro Paolino[1,2*], Caroline Testa José[3], Renata Carolina Fernandes-Santos[3,4], Mariana Bueno Landis[1,5], Gabriela Medeiros de Pinho[3,4] and Emília Patrícia Medici[3,4,6]

[1]Laboratório de Ecologia, Manejo e Conservação da Fauna Silvestre (LEMAC), Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo (ESALQ-USP), Piracicaba, São Paulo, Brazil, [2]Laboratório de Ecologia e Conservação (LAEC), Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Universidade de São Paulo (FFCLRP-USP), Ribeirão Preto, São Paulo, Brazil, [3]Iniciativa Nacional para a Conservação da Anta Brasileira (INCAB), Instituto de Pesquisas Ecológicas (IPÊ), Campo Grande, Mato Grosso do Sul, Brazil, [4]International Union for the Conservation of Nature (IUCN) Species Survival Commission (SSC) Tapir Specialist Group (TSG), Campo Grande, Mato Grosso do Sul, Brazil, [5]Instituto Manacá, São Miguel Arcanjo, São Paulo, Brazil, [6]Escola Superior de Conservação Ambiental e Sustentabilidade (ESCAS), Instituto de Pesquisas Ecológicas (IPÊ), Nazaré Paulista, São Paulo, Brazil

Introduction: Understanding human-wildlife interactions is critical to overcoming the socio-environmental crises we face worldwide. Among these interactions, poaching and hunting, human-wildlife conflict, and transmission of zoonotic diseases are major causes of biodiversity loss and detrimental to human well-being. Therefore, this study aimed to analyze wildlife poaching, feral pig hunting, human-wildlife conflict, and health issues in a region of the Brazilian Cerrado, in the state of Mato Grosso do Sul. The study also focused on the lowland tapir (*Tapirus terrestris*), a poached species listed as vulnerable to extinction.

Methods: From October 2016 to September 2017, we conducted face-to-face semi-structured interviews with 51 local people from nine stakeholder groups. Interview answers and additional information compiled during the study were evaluated using coding, narrative, and co-occurrence analyses.

Results and discussion: We found that the main human-wildlife conflict in the region involves feral pigs, and hunting is practiced as a population control strategy. The lowland tapir is not considered a conflictual species, as it is beloved by most people. However, tapirs are still poached, although less so than in the past, mainly for cultural reasons. Culture was the main motivation behind wildlife poaching in general. We identified 28 species and five taxa currently poached in this Cerrado region, of which 11 are used for medical and aphrodisiac purposes. Historically, wildlife poaching was linked to poor livelihood conditions and lack of support from governmental institutions during the Agrarian Reform process, becoming a cultural habit over the years. Nevertheless, wildlife poaching is less frequent than in the past, and its main barriers are surveillance, poaching prohibition by landowners, and social norm. Therefore, promoting a change in the way people relate to nature, meeting socioeconomic needs, and increasing surveillance appear to be important

conservation strategies. Although feral pig hunting may replace wildlife poaching, some hunters still poach wild species, especially peccaries. Hence, it is necessary to keep hunters under surveillance, raise awareness among them, and make them allies in conservation strategies. We found a worryingly low level of awareness about disease transmission risk through bushmeat manipulation and consumption, highlighting the importance of One Health approaches.

KEYWORDS

Cerrado, *Tapirus terrestris*, wildlife poaching, human-wildlife coexistence, human-wildlife conflict, feral pig hunting, zoonotic diseases, qualitative analysis

Introduction

Around the globe, we are facing a socio-environmental crisis characterized by biodiversity loss, climate change, the emergence of zoonotic diseases, poverty, and inequality (Suša, 2019; Schmeller et al., 2020). These complex problems are intimately linked to human-wildlife interactions, which are decisive elements for wildlife conservation and human well-being (Frank et al., 2019). Relationships between people and wildlife have historically shaped human and wildlife evolution; however, these interactions are becoming more frequent worldwide due to urban and agricultural expansions over native habitats, the recovering of a number of wildlife populations, and the increase of outdoor recreational activities (Marchini and Crawshaw, 2015; Nyhus, 2016). Human-wildlife interactions have a range of outcomes that include cases in which: both humans and wildlife are harmed; only wildlife is harmed (conservation problem); only people are harmed (social problem); none of the parties are negatively impacted (characterized as coexistence); and both parties are positively impacted, achieving conviviality (Marchini et al., 2021). Diverse dimensions – ecological, psychological, social, economic, cultural, and political – influence how people perceive wildlife (Bathia et al., 2019), which directly shape human behavior and, consequently, its impacts on the environment (Jacobs et al., 2012). Thus, the study of the human dimensions of wildlife conservation is an interdisciplinary field that combines natural and social sciences and is crucial to overcoming the current worldwide socio-environmental crisis (Mascia et al., 2003; Decker et al., 2004; Kareiva and Marvier, 2012; König et al., 2020).

Two types of human-wildlife interactions are particularly important to biodiversity conservation and social justice: poaching and hunting (the illegal and legal acts of killing a wild animal, respectively; Ripple et al., 2016), and human-wildlife conflict (IUCN, 2023). FAO (2021) defines human-wildlife conflict as "struggles that emerge when the presence or behavior of wildlife poses an actual or perceived, direct and recurring threat to human interests or needs, leading to disagreements between groups of people and negative impacts on people and/or wildlife". Human-wildlife conflicts can reinforce the motivations behind poaching and hunting, for example when wildlife damages private property or poses any level of threat (actual or perceived) to people's lives, livelihoods, and well-being (Zimmermann et al., 2010; Rizzolo et al., 2016). This may lead to retaliatory killing, a significant cause of wildlife population declines (Linkie et al., 2007; Cavalcanti et al., 2010; Dickman et al., 2013; Puri et al., 2020). However, there are many other important motivations for poaching and hunting, which depend on socioeconomic and cultural contexts and norms (Rizzolo et al., 2016). According to a global assessment made by Ripple et al. (2016), the primary reason is to acquire meat for human consumption, followed by medicinal purposes. Some studies also indicate incidences of poaching and hunting for commercial purposes (Santos et al., 2022). While millions of people around the world rely on bushmeat for their livelihood (Roe and Elliott, 2006), poaching and hunting are among the main threats to vertebrate populations (Schipper et al., 2008). Poaching and hunting are the second largest drivers of mammal extinctions and have synergistic effects with other threats, such as habitat loss (Bogoni et al., 2022). A total of 301 terrestrial mammal species around the world are threatened with extinction due to bushmeat hunting (Ripple et al., 2016). Nevertheless, the words poaching and hunting have not always had distinct meanings throughout human history, and a deeper understanding of the complexity of these phenomena is still needed. Hunting roles and receptiveness in society change geographically and over time. Local opinions about hunting can vary from it being a key livelihood activity to a very disapproved act, from a symbol of freedom to an expression of colonialism, having deep social and cultural roots. Hunting regulations are very different among countries, which classify different activities as poaching (Lavadinović et al., 2021).

The profound defaunation caused by poaching and hunting results in the depletion of essential ecosystem services, jeopardizing ecological equilibrium and human food security (Nasi et al., 2011; Ripple et al., 2016; Bogoni et al., 2020a; Bogoni et al., 2020b). To aggravate this situation, bushmeat poaching and hunting have alarming consequences for both animal and human health. These activities increase human contact with wildlife habitats and animal blood and fluids, elevating the risk of zoonotic disease transmission (LeBreton et al., 2006; Subramanian, 2012; Friant et al., 2015; Winck

et al., 2022). This potential exposure to disease may or may not be fully understood by the local communities and little is known about disease risk perception among hunters and poachers in South America (Subramanian, 2012; Peros et al., 2021).

In Brazil, poaching and hunting are nationally widespread activities with profound ecological and sociological impacts. However, these activities have not yet been investigated in some regions, such as the Cerrado biome (Fernandes-Ferreira and Alves, 2017; Santos et al., 2022). In this regard, there is a pressing need for research that assess poaching and hunting local-specific characteristics in the Cerrado, as well as their impact on both wildlife and people. The Cerrado is an extensive tropical savannah spread across 2,031,990 km^2 of central Brazil. It is the second largest Brazilian biome (after the Amazon) and has been recognized as a Global Biodiversity Hotspot (Strassburg et al., 2017). This biome is also the epicenter of economic development in the country due to the continuously expanding occupation of its territory for large-scale agriculture and livestock production. As a result, the Cerrado has already lost 55% of its natural area (Klink and MaChado, 2005), and is one of the most threatened and least protected biomes in Brazil (Sano et al., 2010).

The Cerrado offers a home to one of the most poached species in Brazil, the lowland tapir (*Tapirus terrestris*) – a large, long-lived, wide-ranging herbivore that feeds on a broad variety of plants, seeds, and fruits (Peres, 2000; Medici, 2011; Medici and Fantacini, 2022). This species is the largest terrestrial mammal in South America (Medici and Fantacini, 2022) and has a critical role in the maintenance of biodiversity and ecosystem services. The lowland tapir is a key species for plant community regulation, seed dispersal, carbon storage, and ecosystem restoration (Fragoso, 1997; Painter, 1998; Bello et al., 2015; Paolucci et al., 2019; Villar and Medici, 2021). Lowland tapir populations are subjected to numerous anthropogenic threats, including habitat loss and fragmentation, poaching, roadkill, fires, environmental pollution, increased exposure to diseases from domestic and feral animals, and harassment from domestic dogs (Medici and Desbiez, 2012). These threats resulted in population declines and local extinctions, qualifying the species as Endangered in the Cerrado and as Vulnerable to Extinction in Brazil and globally (Medici et al., 2012; IUCN, 2019). Hence, this study has a special focus on the lowland tapir.

Except for traditional hunting for livelihood purposes, it is illegal to kill native wildlife species in Brazil, and as such, is characterized as poaching. Conversely, population control of introduced feral pigs through hunting has been allowed under specific regulations since 2013 (IBAMA Normative Instruction 03/2013) since it is an exotic invasive species in Brazil, derived from the wild boar (*Sus scrofa*), and has rapidly increased in abundance since 1989, causing severe economic losses and negative environmental impacts (Oliveira, 2012; Pedrosa et al., 2015; Rosa et al., 2018; Pereira et al., 2019). While feral pig hunting may have positive outcomes for wildlife conservation, acting as a substitute to poaching in the Pantanal biome (Desbiez et al., 2011), there is concern that this activity may encourage and facilitate wildlife poaching in other regions of Brazil (Pedrosa et al., 2015). Thus, this subject needs to be investigated in other Brazilian regions to assess the impact of feral pig hunting on wildlife conservation.

Considering the general strong association between human-wildlife conflicts and poaching, as well as the need to better understand poaching and hunting activities in the Cerrado, we conducted interviews with members of local communities aiming to: 1. identify which species are poached and involved in human-wildlife conflicts; 2. investigate poaching and hunting historical drivers in the region; 3. identify current motivations and barriers for poaching and hunting; and 4. assess the perception of the local community about disease exposure from poaching and hunting and bushmeat consumption. These four objectives assess poaching and hunting activities through different angles and dimensions (conflicts, history, motivations, barriers and health), deepening comprehension about these phenomena. Thus, to assess them together will contribute to more effective decision making in conservation and social justice. Beyond the broad discussion about human dimensions, we generate information for two key species for environmental conservation: the lowland tapir and feral pig. We: 5. investigate perceptions towards lowland tapirs, assessing poaching and conflicts with humans; and 6. evaluate the impact of feral pig hunting on native wildlife. Investigating these two species allows for a case-specific understanding of conflicts and poaching/hunting drivers for different types of species from a conservation perspective, a threatened species and an alien invasive species.

Materials and methods

Study area

The study site is a 2,200 km^2 mosaic of different types of land use in the Cerrado of Mato Grosso do Sul state, Brazil (Municipalities of Nova Alvorada do Sul and Nova Andradina; 21°37'S, 53°40'W; Figure 1). The area includes small fragments of native Cerrado habitat (Cerradão fragments, gallery forests, and marshland – 25% of the study area), surrounded by an anthropized matrix dominated by cattle ranching (cultivated pastureland – 56.13%), large-scale agriculture (particularly sugarcane, soybean, and corn – 8%), eucalyptus plantations (3.6%), and the settlements of landless people and rural communities (0.02%). There is no specific governance structure governing human-wildlife interactions in Brazil, which are mostly monitored, regulated and resolved by ICMBio (Chico Mendes Institute of Biodiversity Conservation) and IBAMA (Brazilian Institute of Environment and Renewable Natural Resources). In the study area, poaching and hunting are governed with a top-down approach, based on weakly enforced legislation due to lack of infrastructure and human resources.

Selection of stakeholders

We identified nine relevant stakeholder groups to interview in the study area, based on the criteria that interviewed stakeholders had to be potentially involved directly or indirectly with hunting

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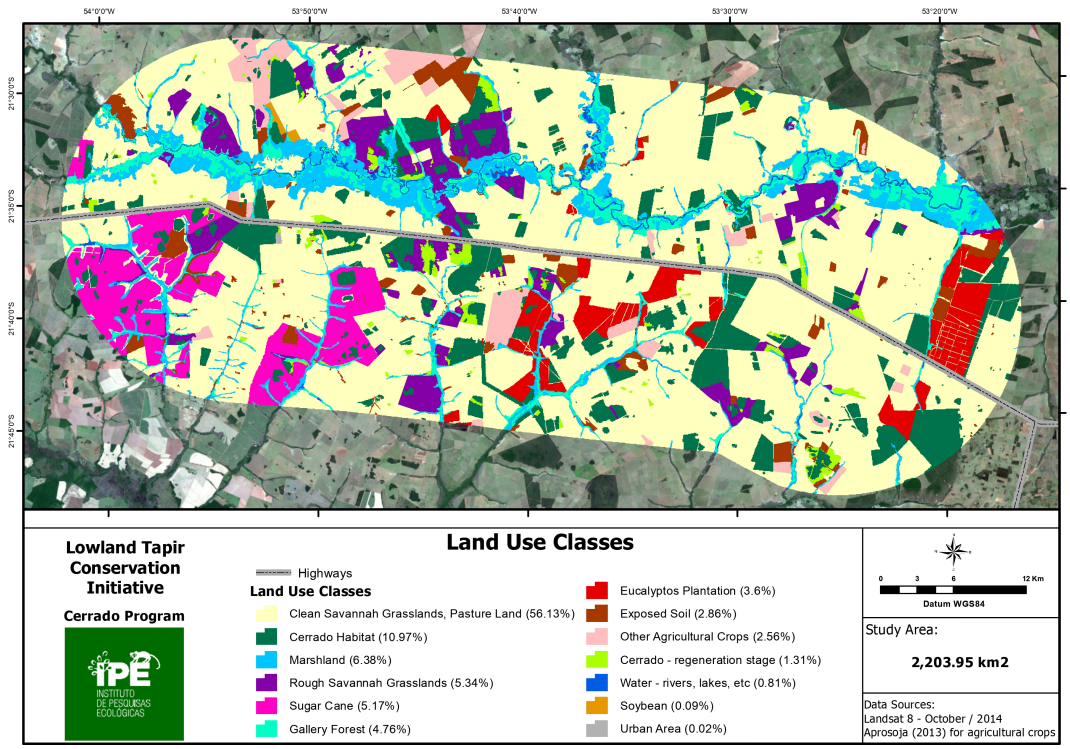

FIGURE 1
Study site in the Cerrado biome, Mato Grosso do Sul state, Brazil.

and poaching: farm and ranch owners, farm and ranch employees, Agrarian Reform settlers, Agrarian Reform campers, residents of rural villages and towns, employees of local agricultural companies (such as sugar production), local hunting club members, police officers (environmental, road, civil, and military), and employees of governmental institutions (State Agency for Animal and Plant Sanitary Defense – IAGRO, Agrarian Development and Rural Extension Agency – AGRAER, National Institute for Colonization and Agrarian Reform – INCRA, and Rural Union).

Interview guide

We designed an interview guide which included 71 questions divided into six sections: 1. General personal information about interviewees – aiming to determine the participant's profile; 2. Poaching and hunting background – questions regarding the characteristics of poaching and hunting in the region; 3. Perceptions and sustainability of poaching and hunting – questions comparing poaching and hunting in the past and present, as well as questions about opinions on if poaching should decrease or be legalized; 4. Human-wildlife conflict – questions regarding if and which wildlife species (and explicitly if the lowland tapir) cause any nuisance or damage, followed by what the problem is, if any, and how the interviewee resolves or would resolve potential conflicts; 5. Health – questions addressing the local knowledge on potential health risks resulting from carcass manipulation and bushmeat consumption, known diseases of domestic and wild animals, as well as prevention and control strategies (such as vaccination and deworming); and 6. Human dimensions – questions about the main motivations behind and barriers to poaching and hunting, social norms, and the nature of the relationship between the interviewees and government institutions. The interview guide consisted of partially open and closed questions that encouraged the interviewees to share their experience, bringing in more valuable information. The interview guide is available in the Supplementary Material.

Data collection

Data were collected through face-to-face semi-structured interviews from October 2016 to September 2017, using the snowball sampling technique, in which the next interviewee is recommended by the previous interviewee. We chose this method to raise the chances of people being willing to participate and of finding people that had knowledge about our research topics (Biernacki and Waldorf, 1981). The team of interviewers (11 researchers) was trained to conduct interviews and record answers in a standardized way. For each interview, at least two researchers visited people at their home or place of work, explaining the study and asking whether they would be willing to be interviewed. We visited two Agrarian Reform settlements, three Agrarian Reform camps, one agrovillage, 19 cattle ranches and farms, six bars/restaurants, and six institutional headquarter offices. Interviewees were selected based on willingness to participate and a

minimum age of 21, which were exclusion criteria. Average interview time was two hours, ranging from 40 minutes to five hours. The team was very careful to try and detect any sign of fatigue or discomfort from our participants, however, we had no sign of exhaustion from our interviewees. The interviews were conducted as informal dialogues guided by the interview guide, without note taking or recording. After the interview, all answers, observations, and additional information were written down. We chose this method to provide a more comfortable environment for the interviewees. Additional information was used as "rich data", which is detailed and varied enough to potentially reveal patterns not detected by the structured answers (Maxwell, 2013). We also compiled information acquired from members of the community that were not formally interviewed. These data were not analyzed but were helpful in better understanding the assessed subjects and discussing the results.

Data analysis

We performed an exploratory data analysis to obtain the profile of interviewees and to compute the percentage of types of responses for each one of the questions. Additionally, the information provided by interviewees was transcribed faithfully into Microsoft Word files (.docx), that were then imported into the software ATLAS.ti 22 (Scientific Software Development GmbH), where we performed coding, a qualitative categorization analysis. The type of data analyzed was the interviewees speech, their answers and reports. Coding is a method that organizes data into subjects of interest and is useful in sorting and describing data, identifying which themes appear in a speech act (Maxwell, 2013; Martins et al., 2022). Complementary to this method, we performed a connecting strategy, narrative analysis, which attempts to understand the data, identifying relationships among the elements of the speech act to understand the context in which the statements are placed. While coding sorts data and organizes the speech in topics of research interest, the narrative analysis connects parts of the speech and gives a deeper understanding of the speech's meaning (Maxwell, 2013).

In the coding analysis, we manually created quotations (i.e., meaningful segments of data) and attributed one or more codes to each quotation. Codes are substantive categories that describe concepts and beliefs of the interviewees. They represent topics that appear in the interviewees' speech, including topics important for this research, and aid in the interpretation of the interviewees' opinions and thoughts. Some codes were grouped into organizational categories that represent broader themes of research interest and describe all the codes included in them (Maxwell, 2013; Martins et al., 2022). For instance, "poached animals" and "wildlife meat consumption" were codes of the "wildlife poaching" code group. Hence, codes were grouped in code groups when they were related to each other and described by the organizational category chosen to represent the code group. We did not generate codes prior to the analysis. Both codes and code groups were created from patterns found in the data throughout the analysis, a deductive process (The complete list of codes and code groups is available in the Supplementary Material). After coding, we assessed the context of each quotation with narrative analysis to create connections among topics of research interest.

- 1st aim: To identify which species are poached and which are involved in human-wildlife conflicts, we computed the number of times a species was cited as poached and as a cause of conflict, using the tool "word list" in the software ATLAS.ti 22, which counted how many times each word (e.g., the common names of the species) appeared in all quotations of the codes "poached animals" and "animals that cause conflict".
- 2nd aim: To characterize these interactions and build a historical framework, we analyzed the context of poaching and conflicts with narrative analysis.
- 3th aim: We assessed how species are culturally used in the region, identifying the animal parts used by people and for which purpose. For assessing poaching and hunting motivations and barriers, as well as aspects related to attitudes favorable and against poaching, we performed an analysis of co-occurrence of codes in the software ATLAS.ti 22. This analysis detects which codes appear together in the same quotation and quantifies how many times they co-occurred, allowing the identification of associated topics (Friese, 2019). The results of the co-occurrence analysis are shown in Sankey diagrams, graphical representations of connections among codes (Friese, 2021).
- 4th aim: In order to assess local community perception of poaching and hunting, bushmeat consumption and zoonosis transmission risk, we used the results of the exploratory analysis to know the proportion of interviewees that are aware of disease exposure and that take any precaution and used narrative analysis to comprehend these behaviors.
- 5th aim: To investigate perceptions, poaching and conflicts regarding lowland tapir, we used the exploratory and the narrative analysis.
- 3th aim: Lastly, to evaluate the impact of feral pig hunting on wildlife, we also used exploratory and narrative analysis.

Results

Profile of interviewees

We interviewed 51 people with 13 different occupations that represented all stakeholder groups. Most interviewees were 'small-scale farmers' (25%), followed by 'traders' (14%) and 'farm and ranch managers' (14%). Regarding stakeholder groups, 'farm and ranch employees' was the best represented group (24%), followed by 'Agrarian Reform settlers' (21%). The group 'governmental institutions' was the least represented (3%). Interviewees were mostly men (84%), older than 41 years of age (from 41 to 50 = 38%; over 50 = 39%), born in the state of the study area (Mato Grosso do Sul = 37%), and have lived in the region for a long time

(more than 15 years = 49%). The complete profile of the interviewees can be found in the Supplementary Material (all personal information was removed from the data).

Coding and most frequently addressed themes

The analysis of the information collected during interviews resulted in 3,116 quotations and 97 codes, organized into 11 code groups (details in the Supplementary Material). The 21 codes with the largest number of quotations (> 50) are shown in Figure 2, representing the most frequently addressed themes during interviews.

The five most frequent codes in interviewees' speech were: 'poaching and hunting motivations' (148 quotations), 'animals that cause conflict' (134), 'depredated crops and livestock' (131), 'appearance of the animal's health' (111), and 'animal diseases in the region' (103), respectively. Thus, interviewees frequently commented on the potential drivers for poaching and hunting, aspects of human-wildlife conflicts, and animal health while answering our questions.

Patterns in human-wildlife conflict

A total of 35 species were involved in human-wildlife conflicts according to the interviewees (Supplementary Material). These species include different taxonomic groups (mammals, birds, lizards, snakes, and caimans), but the most frequently cited species, found by the word count analysis, were the feral pig (*Sus scrofa*; 68 citations), large cats (jaguar, *Panthera onca*, and puma, *Puma concolor*; 57 citations), and the lowland tapir (*Tapirus terrestris*; 21 citations).

Feral pigs depredate sugarcane, soybean, corn, and cassava plantations and eat newborn calves and chicks, causing serious economic losses in the region according to the information obtained through the interviews. Interviewees were aware that the feral pig is an invasive alien species with legalized hunting and were able to morphologically differentiate them from the native wildlife. Therefore, retaliatory killing of feral pigs is very common in the region as a strategy to manage this conflict, as we can see by an interviewee's speech: "The feral pig is considered a pest in the region (…) Farmers and ranchers have the habit of getting hunters to come and kill or frighten them away".

According to interviewees, jaguars and pumas depredate calves, cattle, sheep, lamb, pigs, and chickens in this study area. Reactions to this conflict, however, varied among interviewees. Whereas some (8%) consider depredation as something natural and forbid poaching on their properties, another 10% of the interviewees reported retaliation against big cats, as we can see in the following quotations: "(…) poachers are hired to kill jaguars and pumas that are depredating livestock"; "Ranchers did not hesitate to kill big cats that depredate calves".

The lowland tapir, on the other hand, despite being the third most-cited species for causing conflicts in the region, was not regarded as a conflictual species, that is, no attitude was identified that would result in damage to the species by the people whose crops were consumed. Interviewees reported that lowland tapirs depredate corn, cassava, pumpkin, pequi, sugarcane, soybean, bean, pineapple, potato, watermelon, and papaya plantations. Moreover, tapirs are considered a nuisance by some hunters because they eat the bait used to attract feral pigs, disturbing hunting. Interviewees also reported that tapirs damage rubber trees to lick its sap, eat its

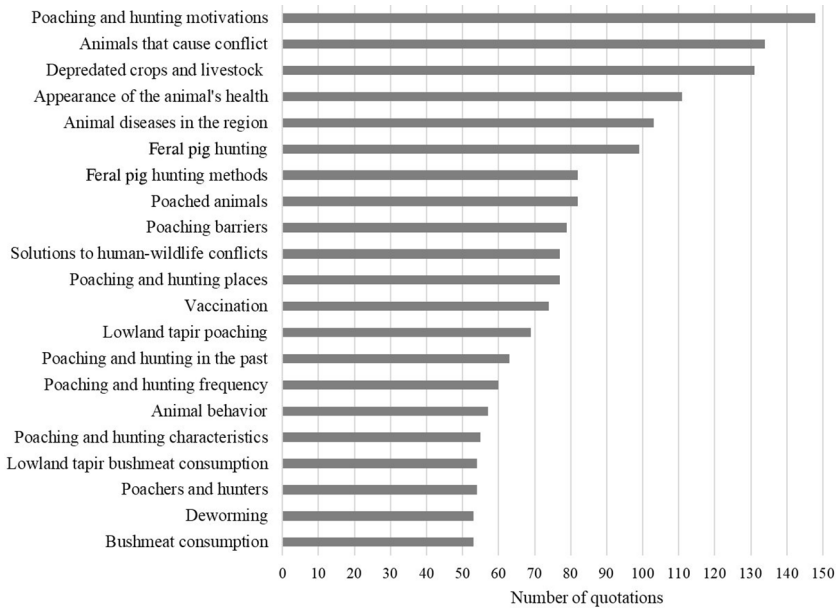

FIGURE 2
Codes with the highest number of quotations (> 50), representing the most frequently adressed themes by the interviewees.

nuts, and nibble stems, which increases the risk of the tree falling. Nevertheless, 58% of interviewees understood the impact caused by tapirs to be insignificant, and there was no report of tapir retaliatory killing in the region. Although 42% of interviewees said that tapir impacts are significant, their speech and reports show that they do not see the lowland tapir as a problem: "I cannot understand poaching, especially of species that do not cause economic losses, like the tapir"; "We do nothing against the tapir that eats cassava, sugarcane, and pumpkin because we feel sorry for it and believe the tapirs are hungry"; "Lowland tapirs do not harm the local rural residents in any way".

Perceptions of the lowland tapir

Our results from the narrative analysis show that the studied communities like and care about lowland tapirs. Interviewees consider tapirs to be gentle, docile, and peaceful, which, according to them, makes them easy to poach. One interviewee highlighted: "The tapir is the most protected species by everybody. It is loved by farmers". In general, interviewees maintain that "there are a lot of tapirs in the region". The majority (75%) think future generations will see lowland tapirs in the wild. In fact, some interviewees (11.8%) questioned if the lowland tapir is really threatened with extinction, showing incredulity regarding its conservation status: "I think it is unlikely that the lowland tapir will become extinct". Regarding changes in tapir population in the region however, interviewees' opinions diverged: 43% think the number of lowland tapirs has decreased, 40% think it has increased, and 17% think it has remained stable. Interviewees who perceived the population to be decreasing believed this to be a consequence of wildlife-vehicle collisions, poaching, harassment by dogs, and the habitat loss related to the conversion of natural habitat to agriculture, particularly sugarcane. On the other hand, interviewees that perceived the population as increasing think this is a result of a rise in resource availability (corn, soybean, sugarcane, and sources of water), a decrease in poaching, the closure of coal mines, and the demarcation of Areas of Permanent Protection – areas protected by the Native Vegetation Protection Law of Brazil (Law N° 12.651/2012), such as gallery forests, steep slopes, and hilltops. Additionally, they say the number of tapir sightings on highways has increased, which raises concerns regarding collisions with vehicles.

Poaching: history, species poached, motivations, and barriers

The narrative analysis results show that poaching history in the region is closely related to the economic activities that emerged over the years, as well as to the process of Agrarian Reform. We identified six peaks of poaching in the study area. The first peak took place when coal mines were established during the 1980s – a period recognized as one in which poaching was most intense in the region. Interviewees reported that, at that time, people would poach mainly as a hobby and because bushmeat was appreciated. The second peak was in the early 1990s, with the beginning of the Agrarian Reform process in the region. Around 1993, wildlife poaching was common, and the lowland tapir was rarely seen in the region. A third and important peak took place in the late 1990s, with the establishment of two large landless people settlements and agrovillages. Interviewees reported an increase in poaching with the arrival of settlers who relied on bushmeat, including tapirs, for their subsistence. The fourth peak of poaching occurred during the 2000s, with the establishment of another important settlement in the region, when poaching was said to be intense. There was a fifth peak during the construction of a power line, and the last peak occurred in 2014, when immigrants arrived to work on the eucalyptus plantations.

One important result from the narrative analysis was the relationship between poaching, working conditions, and the Agrarian Reform process, as we can see in the following quotations: "At the time of the coal mine (…) employers supplied food, including jerked beef, but, when the meat ran out, laborers poached. They used to poach a lot"; "When land settlers arrived, they poached a lot"; "At the time of the landless people camps, nine-banded armadillos, white-lipped peccaries, collared peccaries, lowland paca, agouti, and birds were poached to subsist, due to necessity".

Interviewees mentioned that 28 wildlife species and five taxa (represented by popular names that include several species: birds, rodents, caiman, big cats, armadillo, and deer) are currently poached in the region (Supplementary Material). The capybara (*Hydrochoerus hydrochaeris*) was the most cited among poached species, followed by collared and white-lipped peccaries (*Dicotyles tajacu* and *Tayassu pecari*), feral pigs, and lowland paca (*Cuniculus paca*). In sixth place, lowland tapirs, deer (*Mazama* sp.), and nine-banded armadillos (*Dasypus novemcinctus*) were equally cited. Among the species cited as poached, seven are threatened with extinction in Brazil: the white-lipped peccary, lowland tapir, giant anteater (*Myrmecophaga tridactyla*), marsh deer (*Blastocerus dichotomus*), maned wolf (*Chrysocyon brachyurus*), amazon (*Amazona* sp.), and curassow (Portaria MMA N° 148/2022).

These species are poached for several reasons. We found 11 different motivations behind poaching and hunting in the study area (details in Supplementary Material). The exploratory analysis of the interviewees' direct answers to the question "What is the reason for poaching or hunting?" showed that 'culture' (25%) and 'pleasure/leisure' (25%) were the main motivating factors. 'Human-wildlife conflict' came in next, reflecting 18% of responses, followed by 'feral pig population control' (8%) and 'subsistence/necessity' (6%). The word list analysis revealed that most people associate poaching with meat consumption, since words like 'meat' (41 citations), 'food' (8), and 'feeding' (6) were frequent. 'Necessity' (13) and 'subsistence' (8) also represented an important motivation, followed by cultural reasons ('cultural' = 20). Co-occurrence analysis of the code 'poaching and hunting motivations' reinforced the importance of cultural aspects and conflict as main reasons for poaching and hunting. In the Sankey diagram (Figure 3) we can see that the code 'poaching and hunting motivations' is strongly related to cultural codes (e.g., 'aphrodisiac use', 'medicinal use' and 'cultural aspects') as well as to conflictual codes (e.g.,

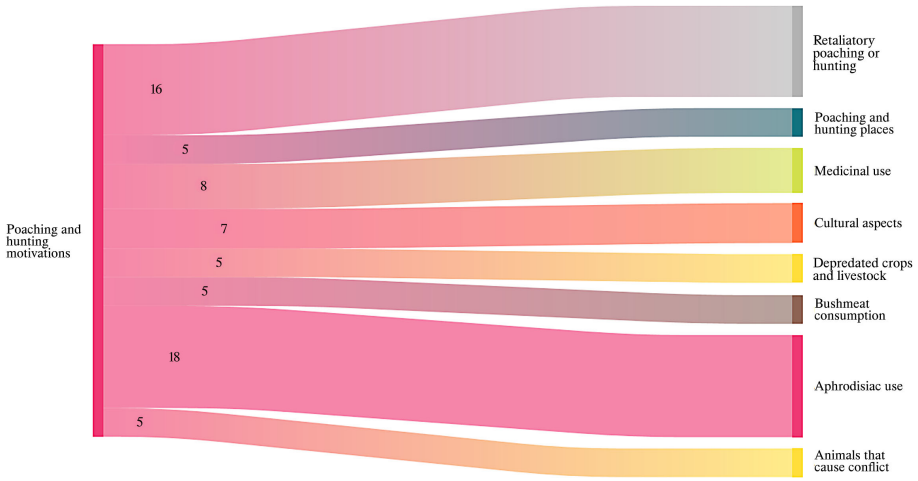

FIGURE 3
Sankey diagram representing the codes that most frequently co-occurred (> 5 co-occurrences) with the code 'Poaching and hunting motivations', showing to what degree these topics were associated. In the Sankey diagram, each code is a node and codes that co-occur are linked by edges. The width of an edge is proportional to how many times codes co-occurred.

'retaliatory killing', 'animals that cause conflict', and 'depredated crops and livestock').

We identified 11 species used for medicinal or aphrodisiac purposes in the study area (Table 1). The lowland tapir had the largest variety of uses, including their fat and feet to treat bronchitis and hooves to treat back pain. Their fat is also used as a strengthening tonic and to treat wounds, while their feet and penis are commonly used as aphrodisiacs. Another species that is largely poached for medicinal purposes is the anaconda (*Eunectes* sp.). Its fat is used to treat bronchitis, back pain, rheumatism, burns, and wounds.

Despite all these motivations, there are important barriers acting to reduce poaching in the study area. We identified at least eight barriers to poaching and hunting with the exploratory analysis (Supplementary Material). Surveillance was considered the main barrier by most interviewees (30.67%), followed by 'prohibition by landowners' (18.67%) and 'legislation' (16%). Qualitative analysis revealed other important barriers to poaching such as the social norms against poaching and hunting, the presence of regulatory and surveillance institutions, the legalization of feral pig hunting, and the presence of the IPÊ Lowland Tapir Conservation Initiative (a conservation project) in the region. Interviewees reported that poaching has decreased over time because nowadays it is easier to acquire food, wildlife populations have decreased, surveillance has increased, along with the presence of the Brazilian Institute of the Environment and Renewable Natural Resources – IBAMA and better living conditions. As a result of the co-occurrence analysis, the Sankey diagram, represented in Figure 4, reinforces the importance of 'surveillance', 'social norms against poaching and hunting', and 'feral pig hunting legalization' as poaching barriers. Results demonstrated that people stop poaching for several reasons, mostly because they start to feel empathy for the animals, but also due to the easier access to buying livestock meat, landowners that forbid poaching on their properties, loss of interest in the activity or lack of time to poach, and current legislation and surveillance. Interestingly, some other additional reasons not to poach mentioned by the interviewees were: fear of guns, concerns about the presence of pesticides and infectious diseases in bushmeat, poacher health, and the association of poaching to childhood in older generations (i.e., poaching used to be considered child's play, and now, these former poachers are adults).

Poaching: frequency, attitudes, and social norms

Exploratory analysis revealed that most interviewees (86.67%) said that wildlife poaching has decreased in recent years and that feral pig hunting has increased. In general, feral pig hunting is considered common in the region while wildlife poaching is uncommon. The following quotations exemplify the perception of people regarding poaching frequency nowadays: "Poaching happens but has decreased a lot. It was a common habit a short while ago (…) People still poach, but less than before"; "(…) in the past, poaching was very common and was attributed mainly to Agrarian Reform campers and settlers. Now, it has decreased". However, we had some reports of high poaching frequency in specific areas, and it was also mentioned that hunters may focus on particular species. Capybara poaching is considered common in the region. Poaching appears to be frequent near sugarcane plantations and at landless people settlements and villages.

The code 'individual negative attitude towards poaching and hunting' appeared more among interviewees (43 quotations) than the code 'individual positive attitude towards poaching and hunting' (15). On the other hand, 'social norms favorable to poaching and hunting' was more frequent among interviewees (32) than 'social norms against poaching and hunting' (23). In general, people agree with and support feral pig hunting, whereas they do not agree with wildlife poaching (peccaries being an exception).

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TABLE 1 The body parts of the species used for medical and aphrodisiac purposes in the study region in the Cerrado biome, Mato Grosso do Sul state, Brazil.

Species	Body part	Used for
Lowland tapir *(Tapirus terrestris)*	fat	bronchitis treatment
	fat	strenghtening
	fat	treatment for wounds and bruises
	foot	bronchitis treatment
	hooves	back pain treatment
	penis	aphrodisiac
	foot	aphrodisiac
Capybara *(Hydrochoerus hydrochaeris)*	fat	bronchitis treatment
		treatment for colds
Caiman	fat	bronchitis treatment
Anaconda (*Eunectes* spp.)	fat	bronchitis treatment
	fat	back pain treatment
	fat	rheumatism treatment
	fat	treatment for burns and wounds
Six-banded armadillo *(Euphractus sexcinctus)*	fat	bronchitis treatment
		diverse diseases
Monkey	head	bronchitis treatment
Giant anteater *(Myrmecophaga tridactyla)*	hair	asthma treatment
Greater rhea (*Rhea americana*)	gizzard	bronchitis treatment
Collared peccary (*Dicotyles tajacu*)	hair	not mentioned
Maned wolf *(Chrysocyon brachyurus)*	eye	aphrodisiac
Coati (*Nasua nasua*)	penis	aphrodisiac

Some interviewees did not identify wildlife at species level, referring to them as the common name of a species group.

Co-occurrence analysis revealed that 'social norms favorable to poaching and hunting' was related to 'feral pig hunting' (13 co-occurrences), which was also linked to 'individual positive attitude towards poaching and hunting' (8), showing a certain relation, although weak, to 'retaliatory killing' (2) and to 'animals that cause conflict' (1). Although most interviewees were against poaching, a few were favorable to wildlife poaching (5.9%), and we received reports that poaching is well-accepted among Agrarian Reform campers and settlers. A negative attitude towards poaching and hunting, on the other hand, was related to a positive attitude towards nature. Moreover, social norms against poaching and hunting were related to barriers to poaching (8 co-occurrences) and to the media. Interestingly, radio shows have had a role in building this social norm, contributing to environmental awareness.

Lowland tapir poaching

There was a consensus among interviewees that the lowland tapir was among the most poached species in the past due to its importance as a food resource. Responses about current tapir poaching, however, diverged. While 57.9% of interviewees reported that tapirs are still being poached, 42.1% said that no one in the region poaches tapirs anymore. Despite these contrasting opinions, most agree that tapir poaching has decreased over the years. The following quotation illustrates the reasons: "I believe that nowadays few people are interested in tapir poaching because of the excessive amount of meat, due to feral pig hunting, which is legalized, and because feral pig meat is more appreciated, and tapirs do not cause harm to local residents". Nevertheless, our results show that the lowland tapir is still poached in some regions, especially near rivers and streams. In addition, there were reports of tapirs that were shot dead, and others that were wounded by snares.

Exploratory analysis revealed that the most frequently used method to poach tapirs is active search and approach for close range shooting (35%), followed by the use of dogs (22%), stakeouts using bait (20%), snares (11%), and traps (11%). The main motivation behind tapir poaching was cultural (56%). In addition, some people poach tapirs to feed their dogs (15%), as a livelihood (15%), for medicinal purposes (7%), and for commercialization of their meat (4%). Tapir meat is mostly prepared and consumed mixed with pork

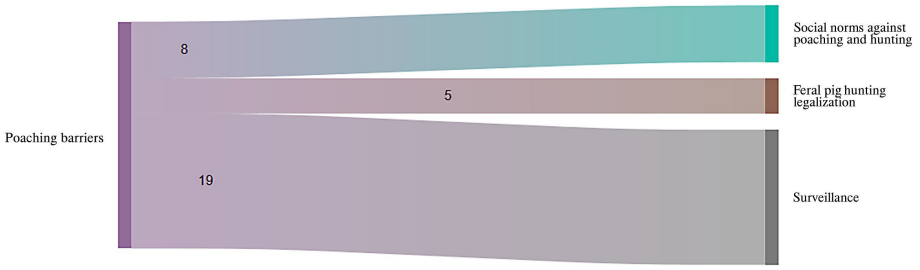

FIGURE 4
Sankey diagram representing the codes that most frequently co-occurred (> 5 co-occurrences) with the code 'Poaching barriers', showing to what degree these topics were associated. In the Sankey diagram, each code is a node and codes that co-occur are linked by edges. The width of an edge is proportional to how many times codes co-occurred.

or peccary meat, in the form of sausage or dried out. Most people that have tasted tapir meat reported not liking it (73.9%). Although a few people think it is tasty and tender, the majority described tapir meat as dry, hard, dark, red, smelly, rubbery, rancid, and strong- or bad-tasting. Interviewees said that tapir meat is not as appreciated as the meat of other species. They also highlighted the fact that it is difficult to carry a poached tapir carcass due to its size and weight, so the meat is wasted in some cases, which discourages poaching.

Relationship between feral pig hunting and wildlife poaching

There are different perceptions about the relationship between feral pig hunting and wildlife poaching. Exploratory analysis revealed that while 53.57% of interviewees claimed that feral pig hunting has caused a decrease in wildlife poaching, 46.43% stated that it facilitates wildlife poaching. On the one hand, part of the interviewees reported that wildlife poaching was replaced by feral pig hunting because it was made legal, and people generally appreciate feral pig meat. This result is exemplified by these quotations: "Wildlife poaching does not happen anymore in the region, it was replaced by feral pig hunting"; "Wildlife poaching decreased with the advent of feral pig hunting". The local hunting club told us they advise its members not to poach and only to hunt feral pigs. According to them, anyone who disrespects this rule faces consequences because it harms the reputation of the group. On the other hand, other interviewees reported that hunters poach every animal they encounter during the hunt, particularly peccaries, as exemplified in these quotations: "I really like collared peccary meat. When we do not find a feral pig, we poach a collared peccary instead"; "If a lowland paca appears during feral pig hunting, it becomes the target"; "I also kill white-lipped and collared peccaries when I see them during feral pig hunting".

Bushmeat consumption and health

The community demonstrated a low level of awareness of the infectious diseases that can be transmitted through bushmeat consumption. Most interviewees were not worried about this since they believed wild animals to be healthier and cleaner than domestic animals, as if bushmeat were organic food. We found through the exploratory analysis that only 33.33% of interviewees demonstrated concern regarding bushmeat consumption. Among the concerns, revealed by the narrative analysis, a "worm that goes to the head" was mentioned, along with a disease provoked by frog consumption, scabs caused by armadillo meat consumption, and some people were afraid to eat scavenger animals, such as caimans, six-banded armadillos, and feral pigs. Interestingly, one person demonstrated concern regarding the presence of pesticides in bushmeat. This person decided to stop poaching and has avoided eating bushmeat since being informed that pesticides had been found in lowland tapirs (Fernandes-Santos et al., 2018). Regarding preventive actions, only 25.5% of interviewees actively took precautions to avoid diseases from bushmeat. The most used preventive action was 'to cook or fry the bushmeat' (61.54%), followed by 'to freeze the bushmeat' (30.76%) and 'to preserve bushmeat in salt' (7.7%).

Discussion

This study has assessed the human dimensions of wildlife conservation in the Brazilian Cerrado from an integrative approach that aims to comprehend the relationships between poaching, hunting, human-wildlife conflicts, and health. To the best of our knowledge, there is one study about wildlife poaching and hunting in this biome (Becker, 1981), and previous studies have assessed poaching and hunting in Indigenous lands (Paula et al., 2017; Dario, 2019). Therefore, our results bring novel information regarding human-wildlife interactions that can help the development of policies, and of conservation and social actions to promote human-wildlife coexistence (Fernandes-Ferreira and Alves, 2017; Marchini et al., 2021).

Patterns in human-wildlife conflict

According to our results, conflict did not appear as a reason for lowland tapir poaching, given that the impact of tapirs on crops was not perceived as detrimental by most interviewees, and there was no report of tapir retaliatory killing in the region. Borges et al. (2020) also had similar findings regarding the absence of conflicts with lowland tapir in the Cerrado biome while Pianca and Monteiro (2005) reported that conflicts with lowland tapirs were a relevant issue in the Atlantic Forest. Although lowland tapirs appeared as the third most-cited species to cause conflict in our study area, we believe this result reflects the fact that all interviewees were questioned specifically about the lowland tapir, the focus of the study.

In our study site, the main human-wildlife conflict involved feral pigs, which is coherent with the relationship we found between 'individual positive attitude to poaching and hunting' and 'feral pig hunting', 'retaliatory killing', and 'human-wildlife conflicts'. In fact, feral pig hunting is used as a strategy to resolve conflicts with the species in the region. Similarly, property defense was the main motivation for feral pig hunting found by Rosa et al. (2018) among Brazilian feral pig controllers. They reported losses in agricultural production, such as sugarcane, corn, and cassava, some of the crops also reported by our interviewees as depredated by feral pigs. Feral pig attacks on crops were also reported in a study conducted around a national park in the Atlantic Forest biome, where most respondents were favorable to control measures and the eradication of this species (Pereira et al., 2019).

Large cats were the second group with the highest number of conflicts. However, retaliatory killing of jaguars and pumas divided opinions in our study area. Although killing big cats to end conflict was not unanimous among interviewees, we found that jaguars and pumas are still persecuted in the Cerrado, which is problematic considering that jaguars are endangered, and pumas are vulnerable to extinction in this biome (de Azevedo et al., 2013; Morato et al., 2013). There are several efficient measures to prevent livestock depredation by big cats (Cavalcanti et al., 2015). Thus, we highlight

the need for planning for human-wildlife coexistence with big cats (Marchini et al., 2021) in the Cerrado to avoid population declines of these felids and to prevent socioeconomic losses.

Poaching in the Brazilian Cerrado

Human-wildlife conflicts appear to be catalysts for poaching and hunting in our study area; however, the most important driver of these practices was culture. Hunting is considered a cultural trait of the Neotropics and a deeply rooted cultural practice in Brazil (Fernandes-Ferreira and Alves, 2017; Ferreguetti et al., 2019). Culture was also the main motivation for lowland tapir poaching, and the use of tapir body parts for medicinal and aphrodisiac purposes stood out. Apart from the lowland tapir, 10 other species were poached for medicinal purposes in the study area. Ungulates are among the main species hunted for medicinal use globally (Ripple et al., 2016). According to Santos et al. (2022), cultural reasons, such as traditional medicine, represent high risk for lowland tapirs in Brazil. For this reason, awareness campaigns focused on lowland tapirs and other wildlife should consider these cultural aspects to obtain an ethically just approach and effectively achieve conservation goals. Awareness campaigns can be ineffective in changing behaviors when social and cultural aspects are neglected. They need political and societal support and should include stakeholders in all steps, from planning to decision-making (Fukushima et al., 2021). Our study also showed that habits and cultural practices are changing in younger generations, which are not as engaged in poaching as those before.

The need for bushmeat for subsistence was also a relevant motivation behind wildlife poaching and hunting in our qualitative analyses. Our reconstruction of the poaching history of the region reinforced the role of socioeconomic factors on poaching activity and the permanence of poaching culture over the years. Poor socioeconomic conditions and lack of support for laborers and Agrarian Reform campers/settlers led to an increase in poaching. This is in no way particular to the Cerrado, as both cultural and economic factors predicted bushmeat consumption and preference in the Brazilian Amazon (Morsello et al., 2015), and in Tanzania (Knapp et al., 2017). Poverty is widely considered the leading driver of poaching worldwide; however, illegal hunting motivations are complex and need to be understood in their historical, social, and political contexts (Duffy et al., 2016). Our results highlight that the lack of support from governmental agencies during the implementation of Agrarian Reform projects (Faisting and Marschner, 2015) has had serious consequences for biodiversity conservation. Thus, we emphasize the crucial importance of people having their basic needs met to decrease pressure on wildlife and highlight the need to consider cultural aspects in developing strategies to reduce poaching and improve social conditions.

The interviewees identified several reasons to stop poaching, which, together with the barriers to poaching, have significant potential for use in the development and implementation of conservation strategies (Duffy et al., 2016). Surveillance and social norms against poaching were two key barriers and reasons to stop poaching in our study. These results highlight the importance of surveillance efforts, but also call attention to the fact that laws must be reinforced by social norms to be effective (Rizzolo et al., 2016; Bragagnolo et al., 2019). Poachers adapt their behaviors in response to norms and to their culture. Risk perceptions about poaching also influence poacher decisions (Rizzolo et al., 2016). We found that poaching prohibition by farmers and ranchers, feeling empathy for the animals, and the ability to purchase livestock meat – in comparison to the past – are relevant factors in stopping poaching. Fear of guns and concern about the presence of pesticides and diseases in bushmeat were also cited barriers. Interestingly, this concern shows how important access to information is, thus, encouraging research and scientific communication initiatives. Our results, therefore, corroborate with the theory that feelings, resource dependence, and risk perception are major factors that influence people's behavior towards wildlife (Jacobs et al., 2012; Bathia et al., 2019).

Relationship between feral pig hunting and wildlife poaching

Another factor reported as a reason that could reduce poaching in our study area was the legalization of feral pig hunting. Our study aimed to analyze the role of feral pig hunting for wildlife conservation and add useful information to this debate. While our results corroborate the hypothesis that hunters replaced wildlife poaching with feral pig hunting, as found by Desbiez et al. (2011) in the Pantanal, our study revealed that some feral pig hunters also poach other species, especially peccaries. Therefore, despite potentially decreasing hunting pressure on wildlife, feral pig hunting may also facilitate wildlife poaching (Pedrosa et al., 2015). Future studies should directly quantify wildlife poaching events during feral pig hunts, using methods to identify illegally poached meat (Sanches et al., 2011). Additionally, although Brazilian legislation (IBAMA Normative Instruction 03/2013) establishes that feral pig hunters must be registered, regularly inform their control activities, neither transport live animals nor commercialize products and subproducts of the hunt, among other obligations, we noticed a lack of awareness regarding these laws in the study region. These results highlight the importance of keeping feral pig hunters under surveillance, but above all, it is crucial that feral pig hunters be treated as allies in conservation strategies, raising awareness about conservation among them.

Bushmeat consumption and health

As mentioned above, some interviewees considered the potential presence of diseases in bushmeat as a barrier to wildlife poaching. Nevertheless, the overall awareness of zoonotic disease transmission risk was low: only 33.33% of interviewees demonstrated concern regarding bushmeat consumption. This percentage is much smaller than that found for villagers in Cameroon (74%; LeBreton et al., 2006) and communities in Nigeria (55%; Friant et al., 2015), but a little higher than that found among hunters and traders in Sierra Leone (24%; Subramanian, 2012). Even though awareness seemed to be higher in Cameron and Nigeria, these studies in Africa found that

only a small proportion of respondents took precautions against zoonotic diseases when manipulating or preparing bushmeat, similarly to our results. Despite bushmeat harvest being much higher in Africa than in South America and contributing to food security of more people in Africa (Cawthorn and Hoffman, 2015), both continents show a worrying lack of awareness regarding zoonotic disease transmission through bushmeat consumption. This disregard for zoonotic diseases raises concern because of how high the potential for contamination when consuming and manipulating bushmeat is (Peros et al., 2021). Brito (2020) identified 13 diseases with zoonotic potential in Brazil, with the highest number of diseases occurring in feral pigs, a species whose meat is frequently consumed in our study area. Unfortunately, the Brazilian population is highly susceptible to zoonotic disease outbreaks and epidemics due to its high social vulnerability and growing environmental degradation (Winck et al., 2022). Hence, our results reinforce the need for health awareness campaigns that consider the One Health approach. This will contribute not only to improving human health, but also to livestock health and biodiversity conservation (Buttke et al., 2015; Cunningham et al., 2017).

Perceptions and poaching of the lowland tapir

Interviewees in our study area had a positive perception of lowland tapirs, a similar result to the one found in the Caatinga biome, where there were no reports of negative situations associated with the tapir (Borges et al., 2020). This positive perception represents the acceptance of lowland tapirs in the region, a meaningful result for the conservation of this vulnerable species, especially since positive attitudes towards a species and low risk perception associated with it are key predictors of tolerance and favorable human responses towards wildlife (Jacobs et al., 2012; Bathia et al., 2019). Therefore, conservation efforts in the region may benefit from using the charisma of lowland tapirs as a communication strategy. Although people may like the tapir, there is an aspect of people's perceptions that deserves attention. Some interviewees did not believe this species is threatened with extinction in the region and were incredulous when informed about the species' conservation status. The perception that "there are a lot of tapirs in the region" may be explained by the fact that the lowland tapir is a wide-ranging species (Medici et al., 2022). As such, its movement patterns may increase the detection probability of these animals, especially in a fragmented landscape, where they are restricted to small patches of forest but cross the matrix between forest fragments. On the other hand, the fact that the lowland tapir is well-known by people in the region, is commonly seen and well-recognized is an advantage to the use of this species as a flagship species in the region (Bowen-Jones and Entwistle, 2002).

Nevertheless, the frequency of tapir sightings does not necessarily represent tapir abundance, and studies in the Brazilian Cerrado show that lowland tapir density is low (Desbiez, 2009; Medici et al., 2012). Therefore, we identified a disparity between people's perception and ecological data in our study region regarding the tapir. This result does not diminish the importance of Local Ecological Knowledge for better understanding animal characteristics, which in fact contributes significantly to the understanding of species interactions with the environment (Prado, 2012). Conversely, this result highlights the importance of people as a source of information to develop more effective conservation strategies that consider the perceptions of local communities.

Despite being a beloved species in the study area, the lowland tapir is still poached in this region of the Brazilian Cerrado. The technique most often used for tapir poaching in the study area is active search and approach for shooting. Santos et al. (2022) found that the technique most often used to poach lowland tapirs was stakeouts, which was the third most frequently used method in our study area. Lowland tapir poaching was more frequent near streams and rivers, which is generally their preferred habitat (Medici and Fantacini, 2022). In a fragmented landscape such as our study area, riverine forests function as essential corridors to wildlife movement, which makes them good places for poaching. This raises concern about wildlife and lowland tapir conservation in the region because poaching, although less intensive than in the past, is still frequent in remaining habitats and ecological corridors, regarded as essential landscape elements to biodiversity maintenance. This is especially worrying since previous studies have shown that poaching is one of the major threats to lowland tapirs and found a negative correlation between the level of poaching and the occurrence of tapirs (Cullen et al., 2000; Peres, 2000; Fa et al., 2002; Medici et al., 2007; Cruz et al., 2014; Ferreguetti et al., 2017; Hallett et al., 2019).

Recommendations for human-wildlife coexistence

Our results demonstrate the need to design and establish effective strategies to deal with human-wildlife conflict, poaching and hunting and zoonotic diseases risk that may be useful in similar situations worldwide. We stress the importance of planning for human-wildlife coexistence, including all stakeholders during the entire process, of building capacities among them, and of providing sources of resources to deal with conflicts. We recommend that communities socioeconomic needs must be met and institutional support must be present to effectively achieve conservation goals and promote social justice. Additionally, we strongly recommend that cultural aspects must be considered when dealing with human-wildlife interactions. It is also necessary to raise awareness about conservation among professional hunters, making them allies for implementing conservation strategies, while keeping them under surveillance. We recommend that awareness regarding zoonotic disease transmission through hunting, poaching and bushmeat consumption should be a priority among governments, applying the One health approach. Finally, it is of utmost importance to include human-wildlife interactions in the policy agenda, both globally and regionally.

Conclusions

Historically, in our study area of the Brazilian Cerrado, wildlife poaching was strongly linked to poor livelihood conditions and lack of support from governmental institutions during the Agrarian

Reform process for settlements. According to the interviewees, wildlife poaching has become a cultural habit in the region, increasing substantially during times of necessity. Today, culture is the main motivation behind poaching and hunting, highlighting the need for a change in the ways this community relates to wildlife. This can be achieved through raising awareness about conservation and encouraging other possible interactions, including wildlife observation and photography. Considering our results, the increase in surveillance, the prohibition of poaching by landowners, and the social norms against poaching are effectively acting as barriers to wildlife poaching and, as such, should be considered in future conservation strategies.

Human-wildlife conflict was one of the motivations behind poaching and hunting, especially as it relates to the hunting of feral pigs, the most conflictual species in the study area. The lowland tapir was not considered a conflictual species; to the contrary, it was very appreciated and beloved by most interviewees. The charisma of the lowland tapir should be leveraged for the development of conservation strategies in the region; however, locals must also be informed about the conservation status of tapirs. Locals perceive tapirs to be abundant in the region, which is contrary to the results derived from ecological studies.

In recent years, wildlife poaching has decreased in the studied area studied, and feral pig hunting has increased. Regarding the role of feral pig hunting for biodiversity conservation, we found, based on interviewees reports, that the legalization of feral pig hunting was considered a barrier to poaching, and that feral pig hunting has replaced wildlife poaching in the study area to a certain degree. However, we had reports that hunters still poach other species during hunts.

In addition, we show a strikingly low level of awareness about disease transmission risk through bushmeat manipulation and consumption. This underscores how it is of the utmost importance that poaching and hunting be considered a public health issue in Brazil. The relationship between the lack of basic necessities and an increase in poaching, along with the lack of disease awareness, highlights the intimate relationship between biodiversity conservation and human well-being, both of which should be considered together for the promotion of public policy and the definition of management strategies.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics Committee of Universidade Católica Dom Bosco (UCDB, Brazil) (PLATAFORMA BRASIL CAAE #80897117.6.0000.5162). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

Conceptualization, writing and revising the original draft: RM and EM; Data collection: CT, RF-S, MB, and EM; Data analysis: RM, MB, and EM; Revising the original draft: CT, RF-S, MB, and GM. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcosc.2023.1221206/full#supplementary-material

References

Bathia, S., Redpath, S. M., Suryawanshi, K., and Mishra, C. (2019). Beyond conflict: exploring the spectrum of human–wildlife interactions and their underlying mechanisms. *Oryx* 54 (05), 621–628. doi: 10.1017/S003060531800159X

Becker, M. (1981). Aspectos da caca em algumas regioes do cerrado de Mato Grosso. *Brasil Florestal* 11 (47), 51–63.

Bello, C., Galetti, M., Pizo, M. A., Magnago, L. F. S., Rocha, M. F., Lima,, et al. (2015). Defaunation affects carbon storage in tropical forests. *Sci. Adv.* 1 (11), e1501105. doi: 10.1126%2Fsciadv.1501105

Biernacki, P., and Waldorf, D. (1981). Snowball sampling: problems and techniques of chain referral sampling. *Sociological Methods Res.* 10 (2), 141–163. doi: 10.1177/004912418101000205

Bogoni, J. A., Ferraz, K. M. P. M. B., and Peres, C. A. (2020a). Effects of mammal defaunation on natural ecosystem services and human well being throughout the entire Neotropical realm. *Ecosystem Serv.* 45, 101173. doi: 10.1016/j.ecoser.2020.101173

Bogoni, J. A., Ferraz, K. M. P. M. B., and Peres, C. A. (2022). Continental-scale local extinctions in mammal assemblages are synergistically induced by habitat loss and hunting pressure. *Biolog. Conserv.* 272, 109635. doi: 10.1016/j.biocon.2022.109635

Bogoni, J. A., Peres, C. A., and Ferraz, K. M. P. M. B. (2020b). Extent, intensity and drivers of mammal defaunation: a continental–scale analysis across the Neotropics. *Sci. Rep.* 10, 14750. doi: 10.1038/s41598-020-72010-w

Borges, D. C. S., Pereira, S. G., MaChado, F. C. A., and Santos, A. L. Q. (2020). ANTA BRASILEIRA – *Tapirus terrestris:* características gerais, mitológicas e seu conhecimento popular nas regiões do Noroeste e do Alto Paranaíba em Minas Gerais. *Rev. Pesquisa Interdisciplinar* 5 (1), 289–315.

Bowen-Jones, E., and Entwistle, A. (2002). Identifying appropriate flagship species: the importance of culture and local contexts. *Oryx* 36 (2), 189–195. doi: 10.1017/S0030605302000261

Bragagnolo, C., Gama, G. M., Vieira, F. A. S., Campos-silva, J. V., Bernard, E., Malhado, A. C. M., et al. (2019). Hunting in Brazil: what are the options? *Perspect. Ecol. Conserv.* 17, 71–79. doi: 10.1016/j.pecon.2019.03.001

Brito, L. J. M. (2020). Zoonoses oriundas do consumo de carne de caça. *Práticas e Cuidado: Rev. Saúde Coletiva* 1, e12426,1–5.

Buttke, D. E., Decker, D. J., and Wild, M. A. (2015). The role of One Health in wildlife conservation: a challenge and opportunity. *J. Wildlife Dis.* 51 (1), 1–8. doi: 10.7589/2014-01-004

Cavalcanti, S. M. C., De Paula, R. C., and Gasparini-Morato, R. L. (2015). *Conflitos com mamíferos carnívoros: uma referência para o manejo e a convivência* (Brasília: Instituto Chico Mendes de Conservação da Biodiversidade, ICMBio).

Cavalcanti, M. C., Marchini, S., Zirnmerrnann, A., Gese, E. M., and Macdonald., D. W. (2010). "Jaguars, livestock and people in Brazil: realities and perceptions behind the conflict," in *The biology and conservation of wild felids.* Eds. D. Macdonald and A. Loveridge (Oxford, United Kingdom: Oxford University Press), 383–402.

Cawthorn, D.-M., and Hoffman, L. C. (2015). The bushmeat and food security nexus: A global account of the contributions, conundrums and ethical collisions. *Food Res. Int.* 76, 906–925. doi: 10.1016/j.foodres.2015.03.025

Cruz, P., Paviolo, A., Bó, R. F., Thompson, J. J., and Di Bitetti, M. S. (2014). Daily activity patterns and habitat use of the lowland tapir (*Tapirus terrestris*) in the Atlantic Forest. *Mamm. Biol.* 79, 376–383. doi: 10.1016/j.mambio.2014.06.003

Cullen, J. L., Bodmer, R. E., and Pádua, C. V. (2000). Effects of hunting in habitat fragments of the Atlantic forests, Brazil. *Biol. Conserv.* 95, 49–56. doi: 10.1016/S0006-3207(00)00011-2

Cunningham, A. A., Daszak, P., and Wood, J. L. N. (2017). One Health, emerging infectious diseases and wildlife: two decades of progress? *Phil. Trans. R. Soc B* 372, 20160167. doi: 10.1098/rstb.2016.0167

Dario, F. R. (2019). The relationship between Bororo Indigenous and the wildlife in the Brazilian Savannah. *World News Natural Sci.* 24, 240–250.

de Azevedo, F. C., Lemos, F. G., de Almeida, L. B., de Campos, C. B., de M Beisiegel, B., De Paula, R. C., et al. (2013). Avaliação do risco de extinção da onça-parda *Puma concolor* (Linnaeus 1771) no Brasil. *Biodiversidade Bras.* 3 (1), 107–121. doi: 10.37002/biodiversidadebrasileira.v3i1.377

Decker, D. J., Brown, T. L., Vaske, J. J., and Manfredo, M. J. (2004). "Human dimensions of wildlife management," in *Society and Natural Resources: A Summary of Knowledge.* Ed. M. J. Manfredo (Jefferson, MO, USA: Modern Litho), 187–198.

Desbiez, A. L. J. (2009). Lowland tapirs in the Nhecolândia region of Brazilian pantanal: population density, habitat use and threats. *Tapir Conserv.* 18 (25), 7–10.

Desbiez, A. L. J., Keuroghlian, A., Piovezan, U., and Bodmer, R. E. (2011). Invasive species and bushmeat hunting contributing to wildlife conservation: the case of feral pigs in a Neotropical wetland. *Oryx* 45 (1), 78–83. doi: 10.1017/S0030605310001304

Dickman, A., Marchini, S., and Manfredo, M. (2013). "The human dimensions in addressing conflict with large carnivores," in *Key Topics in Conservation Biology*, vol. 2 . Eds. D. W. Macdonald and K. J. Willis (West Sussex, UK: John Wiley & Sons, Ltd), 110–126.

Duffy, R., St john, F. A. V., Büscher, B., and Brockington, D. (2016). Toward a new understanding of the links between poverty and illegal wildlife hunting. *Conserv. Biol.* 30, 14–22. doi: 10.1111/cobi.12622

Fa, J. E., Peres, C. A., and Meeuwig, J. A. (2002). Bushmeat exploration in tropical forests: an intercontinental comparison. *Conserv. Biol.* 16, 232–237. doi: 10.1046/j.1523-1739.2002.00275.x

Faisting, A. L., and Marschner, W. (2015). *Olhares sobre os assentamentos de reforma agrária em Mato Grosso do Sul.* Ed. M. S. Dourados (Dourados: UFGD).

FAO (Food and Agriculture Organization of the United Nations) (2021) *Addressing the human-wildlife conflict to improve people's livelihoods*. Available at: http://www.fao.org/forestry/wildlife (Accessed January 25, 2023).

Fernandes-Ferreira, H., and Alves, R. R. N. (2017). The researches on the hunting in Brazil: a brief overview. *Etnobiology Conserv.* 6 (6), 1–6.. doi: 10.15451/ec2017-07-6.6-1-6

Fernandes-Santos, R. C., Medici, E. P., Testa-José, C., and Canena, A. C. (2018). *Impacto de agrotóxicos e metais pesados na anta brasileira (tapirus terrestris) no estado do Mato Grosso do Sul, Brasil, e implicações para saúde humana e ambiental. Relatório Técnico* (Campo Grande: Iniciativa Nacional para a Conservação da Anta Brasileira (INCAB) e Instituto de Pesquisas Ecológicas (IPÊ)).

Ferreguetti, A. C., Duarte Rocha, C. F., and Godoy Bergallo, H. (2019). Poaching in non–volant mammals in the Neotropical region: the importance of a metric to assess its impacts. *Anim. Biodiversity Conserv.* 42 (2), 203–211. doi: 10.32800/abc.2019.42.0203

Ferreguetti, A. C., Tomás, W. M., and Bergallo, H. G. (2017). Density, occupancy, and detectability of lowland tapirs, *Tapirus terrestris*, in Vale Natural Reserve, southeastern Brazil. *J. Mammalogy* 98 (1), 114–123. doi: 10.1093/jmammal/gyw118

Fragoso, J. M. V. (1997). Tapir-generated seed shadows: scale-dependent patchiness in the Amazon rain forest. *J. Ecol.* 85, 519–529. doi: 10.2307/2960574

Frank, B., Glikman, J. A., and Marchini, S. (2019). *Human-wildlife interactions: turning conflict into coexistence* (Cambridge, UK: Cambridge University Press).

Friant, S., Paige, S. B., and Goldberg, T. L. (2015). Drivers of bushmeat hunting and perceptions of zoonoses in Nigerian hunting communities. *PloS Negl. Trop. Dis.* 9 (5), e0003792. doi: 10.1371/journal.pntd.0003792

Friese, S. (2019). *Qualitative Data Analysis with ATLAS.ti. 3rd edition* (London: SAGE Publications Ltd), 344. p.

Friese, S. (2021). *ATLAS.ti 9 Windows - User Manual* (Berlin: ATLAS.ti Scientific Software Development GmbH).

Fukushima, C. S., Tricorache, P., Toomes, A., Stringham, O. C., Rivera-Téllez, E., Ripple, W. J., et al. (2021). Challenges and perspectives on tackling illegal or unsustainable wildlife trade. *Biol. Conserv.* 26, 109342. doi: 10.1016/j.biocon.2021.109342

Hallett, M. T., Kinahan, A. A., McGregor, R., Baggallay, T., Babb, T., Barnabus, H., et al. (2019). Impact of low-intensity hunting on game species in and around the Kanuku mountains protected area, Guyana. *Front. Ecol. Evol.* 7. doi: 10.3389/fevo.2019.00412

IUCN (2023). *IUCN SSC guidelines on human-wildlife conflict and coexistence. 1st ed.* (Gland, Switzerland: IUCN).

IUCN – International Union for Conservation of Nature (2019). Available at: https://www.iucnredlist.org/species/21474/45174127 (Accessed January 19, 2023).

Jacobs, M. H., Vaske, J. J., Teel, T. L., and Manfredo, M. J. (2012). "Human dimensions of wildlife," in *Environmental Psychology: An Introduction*. Eds. L. Steg, A. E. Van Den Berg and J. I. M. De Groot (Oxford, UK: Wiley-Blackwell), 77–86.

Kareiva, P., and Marvier, M. (2012). What is conservation science? *BioScience* 62 (11), 962–969. doi: 10.1525/bio.2012.62.11.5

Klink, C. A., and MaChado, R. B. (2005). A conservação do Cerrado Brasileiro. *Megadiversidade* 1 (1), 147–155.

Knapp, E. J., Peace, N., and Bechtel, L. (2017). Poachers and poverty: assessing objective and subjective measures of poverty among illegal hunters outside Ruaha national park, Tanzania. *Conserv. Soc.* 15 (1), 24–32. doi: 10.4103/0972-4923.201393

König, H. J., Kiffner, C., Kramer-SChadt, S., Furst, C., Keuling, O., and Ford, A. T. (2020). Human–wildlife coexistence in a changing world. *Conserv. Biol.* 34 (4), 786–794. doi: 10.1111/cobi.13513

Lavadinović, V. M., Islas, C. A., Chatakonda, M. K., Marković, N., and Mbiba, M. (2021). Mapping the research landscape on poaching: A decadal systematic review. *Front. Ecol. Evol.* 9. doi: 10.3389/fevo.2021.630990

LeBreton, M., Prosser, A. T., Tamoufe, U., Sateren, W., Mpoudi-Ngole, E., Diffo,, et al. (2006). Patterns of bushmeat hunting and perceptions of disease risk among central African communities. *Anim. Conserv.* 9, 357–363. doi: 10.1111/j.1469-1795.2006.00030.x

Linkie, M., Dinata, Y., Nofrianto, A., and Leader-Williams, N. (2007). Patterns and perceptions of wildlife crop raiding in and around Kerinci Seblat National Park, Sumatra. *Anim. Conserv.* 10, 127–135. doi: 10.1111/j.1469-1795.2006.00083.x

Marchini, S., and Crawshaw, J. P.G. (2015). Human–wildlife conflicts in Brazil: A fast-growing issue. *Hum. Dimensions Wildlife* 20 (4), 323–328. doi: 10.1080/10871209.2015.1004145

Marchini, S., Ferraz, K. M. P. M. B., Foster, V., Reginato, T., Kotz, A., Barros, Y., et al. (2021). Planning for human-wildlife coexistence: conceptual framework, workshop

process, and a model for transdisciplinary collaboration. *Front. Conserv. Sci.* 2. doi: 10.3389/fcosc.2021.752953

Martins, C. S. G., Engel, M. T., Guimarães, M. A., Paolino, R. M., Schulz, F., and Esteves, C. F. (2022). Social repercussion of translocating a jaguar in Brazil. *Front. Conserv. Sci.* 2, 788641. doi: 10.3389/fcosc.2021.788641

Mascia, M. B., Brosius, J. P., Dobson, T. A., Forbes, B. C., Horowitz, L., McKean, M., et al. (2003). Conservation and the social sciences. *Conserv. Biol.* 17 (3), 649–650. doi: 10.1046/j.1523-1739.2003.01738.x

Maxwell, J. A. (2013). *Qualitative Research Design: An Interactive Approach. 3rd Edn* (Los Angeles: Sage Publications).

Medici, E. P. (2011). "Family tapiridae (Tapirs)," in *Handbook of the mammals of the world – Volume 2: Hoofed Mammals*. Eds. D. E. Wilson and R. A. Mittermeier (Barcelona: Lynx Editions).

Medici, E. P., and Desbiez, A. L. J. (2012). Population viability analysis: using a modeling tool to assess the viability of tapir populations in fragmented landscapes. *Integr. Zoology* 7, 356–372. doi: 10.1111/j.1749-4877.2012.00318.x

Medici, E. P., Desbiez, A. L. J., Gonçalves da Silva, A., Jerusalinsky, L., Chassot, O., Montenegro, O. L., et al. (2007). *Lowland tapir (Tapirus terrestris) population and habitat viability assessment (PHVA): final report. Relatório Técnico* (Campo Grande: IUCN/SSC Tapir Specialist Group (TSG) and IUCN/SSC Conservation Breeding Specialist Group (CBSG)).

Medici, E. P., and Fantacini, F. M. (2022). Order Perissodactyla: current knowledge about the lowland tapir, with particular focus on the Pantanal biome. *Bol. Mus. Para. Emílio Goeldi. Cienc. Nat. Belém* 17 (1), 000–000. doi: 10.46357/bcnaturais.v17i1.832

Medici, E. P., Flesher, K., Beisiegel, B., de, M., Keuroghlian, A., Desbiez, A. L. J., et al. (2012). Avaliação do risco de extinção da anta brasileira *Tapirus terrestris* Linnaeus 1758 no Brasil. *Biodiversidade Bras.* 2 (3), 103–116.

Medici, E. P., Mezzini, S., Fleming, C. H., Calabrese, J. M., and Noonan, M. J. (2022). Movement ecology of vulnerable lowland tapirs between areas of varying human disturbance. *Movement Ecol.* 10, 14. doi: 10.1186/s40462-022-00313-w

Morato, R. G., Beisiegel, B., de, M., Ramalho, E. E., de Campos, C. B., and Boulhosa, R. L. P. (2013). Avaliação do risco de extinção da onça-pintada *Panthera onca* (Linnaeus 1758) no Brasil. *Biodiversidade Bras.* 3 (1), 122–132. doi: 10.37002/biodiversidadebrasileira.v3i1.378

Morsello, C., Yague, B., Beltreschi, L., van Vliet, N., Adams., C., Schor, T., et al. (2015). Cultural attitudes are stronger predictors of bushmeat consumption and preference than economic factors among urban Amazonians from Brazil and Colombia. *Ecol. Soc.* 20 (4), 21. doi: 10.5751/ES-07771-200421

Nasi, R., Taber, A., and Van Vliet, N. (2011). Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon basins. *Int. Forestry Rev.* 13, 355–368. doi: 10.1505/146554811798293872

Nyhus, P. J. (2016). Human–wildlife conflict and coexistence. *Annu. Rev. Environ. Resour.* 41, 143–171. doi: 10.1146/annurev-environ-110615-085634

Oliveira, C. H. S. (2012). *Ecologia e Manejo de Javali (Sus scrofa, L.) na América do Sul* (Rio de Janeiro (BR: Universidade Federal do Rio de Janeiro).

Painter, R. L. E. (1998). *Gardeners of the forest: plant-animal interactions in a neotropical forest ungulate community* (Liverpool (UK: University of Liverpool).

Paolucci, L. N., Pereira, R. L., Rattis, L., Silverio, D. V., Marques, N. C., Macedo, M. N., et al. (2019). Lowland tapirs facilitate seed dispersal in degraded Amazonian forests. *Biotropica* 5 (2), 245–252. doi: 10.1111/btp.12627

Paula, M., Xerente, V., and Pezzuti., J. (2017). Hunting and monitoring: community-based research in xerente indigenous land, Brazilian Cerrado. *Hum. Ecol. Rev.* 23, 23–43. doi: 10.22459/HER.23.01.2017.02

Pedrosa, F., Salerno, R., Padilha, F. V. B., and Galetti, M. (2015). Current distribution of invasive feral pigs in Brazil: economic impacts and ecological uncertainty. *Braz. J. Nat. Conserv.* 13, 84–87. doi: 10.1016/j.ncon.2015.04.005

Pereira, C. Z., Rosa, C., Zanzini, A. C., and da, S. (2019). Perception of presence, impact and control of the invasive species *Sus scrofa* in the local community living near the Itatiaia National Park, Brazil. *Ethnobiology Conserv.* 8, 6. doi: 10.15451/ec2019-06-8.06-1-11

Peres, C. A. (2000). Effects of subsistence hunting on vertebrate community structure in Amazonian forests. *Conserv. Biol.* 14 (1), 240–253. doi: 10.1046/j.1523-1739.2000.98485.x

Peros, C. S., Dasgupta, R., Kumar, P., and Johnson, B. A. (2021). Bushmeat, wet markets, and the risks of pandemics: Exploring the nexus through systematic review of scientific disclosures. *Environ. Sci. Policy* 124, 1–11. doi: 10.1016/j.envsci.2021.05.025

Pianca, C. C., and Monteiro, R. T. R. (2005). *A caça e seus efeitos sobre a ocorrência de mamíferos de médio e grande porte em áreas preservadas de Mata Atlântica na serra de Paranapiacaba (SP)* (Piracicaba (BR: Universidade de São Paulo).

Prado, H. M. (2012). *O conhecimento de agricultores quilombolas sobre forrageio e uso de habitat por mamíferos de grande porte na Mata Atlântica: Evidenciando a centralidade dos ambientes antropogênicos na constituição do etnoconhecimento (Vale do Ribeira, SP, Brasil)* (São Paulo (BR: Universidade de São Paulo).

Puri, M., Srivathsa, A., Karanth, K. K., Patel, I., and Kumar, N. S. (2020). The balancing act: Maintaining leopard-wild prey equilibrium could offer economic benefits to people in a shared forest landscape of central India. *Ecol. Indic.* 110, 1–10. doi: 10.1016/j.ecolind.2019.105931

Ripple, W. J., Abernethy, K., Betts, M. G., Chapron, G., Dirzo, R., Galetti, M., et al. (2016). Bushmeat hunting and extinction risk to the world's mammals. *R. Soc Open Sci.* 3, 160498. doi: 10.1098/rsos.160498

Rizzolo, J. B., Gore, M. L., Ratsimbazafy, J. H., and Rajaonson, A. (2016). Cultural influences on attitudes about the causes and consequences of wildlife poaching. *Crime Law Soc. Change* 67, 415–437. doi: 10.1007/s10611-016-9665-z

Roe, D., and Elliott, J. (2006). Pro-poor conservation: the elusive win-win for conservation and poverty reduction. *Policy Matters* 14 (03), 53–63.

Rosa, C. A., Wallau, M. O., and Pedrosa, F. (2018). Hunting as the main technique used to control wild pigs in Brazil. *Wildlife Soc. Bull.* 42 (1), 111–118. doi: 10.1002/wsb.851

Sanches, A., Perez, W. A. M., Figueiredo, M. G., Rossini, B. C., Cervini, M., Galetti, P. M. Jr., et al. (2011). Wildlife forensic DNA and lowland tapir (*Tapirus terrestris*) poaching. *Conserv. Genet. Resour.* 3, 189–193. doi: 10.1007/s12686-010-9318-y

Sano, E. E., Rosa, R., Brito, J. L. S., and Ferreira, L. G. (2010). Land cover mapping of the tropical savanna region in Brazil. *Environ. Monit. Assess.* 166, 113–124. doi: 10.1007/s10661-009-0988-4

Santos, F. I. R., de O Santos, E. P., dos S Sousa, F. E., Alencar, J. S., dos S Ferreira, L. S., and Lopes, C. G. R. (2022). A caça da anta (*Tapirus terrestris*) e as implicações para a conservação das florestas brasileiras: uma revisão sistemática. *Rev. Etnobiologia* 20 (1), 84–96.

Schipper, J., Chanson, J. S., Chiozza, F., Cox, N. A., Hoffmann, M., Katariya, V., et al. (2008). The status of the world's land and marine mammals: diversity, threat, and knowledge. *Science* 322, 225–230. doi: 10.1126/science.1165115

Schmeller, D. S., Courchamp, F., and Killeen, G. (2020). Biodiversity loss, emerging pathogens and human health risks. *Biodivers. Conserv.* 29, 3095–3102. doi: 10.1007/s10531-020-02021-6

Strassburg, B. B. N., Brooks, T., Feltran-Barbieri, R., Iribarrem, A., Crouzeilles, R., Loyola, R., et al. (2017). Moment of truth for the Cerrado hotspot. *Nat. Ecol. Evol.* 1, 99. doi: 10.1038/s41559-017-0099

Subramanian, M. (2012). Zoonotic disease risk and the bushmeat trade: assessing awareness among hunters and traders in Sierra Leone. *EcoHealth* 9, 471–482. doi: 10.1007/s10393-012-0807-1

Suša, O. (2019). Global dynamics of socio-environmental crisis. *Civitas Porto Alegre* 19 (2), 315–336. doi: 10.15448/1984-7289.2019.2.31969

Villar, N., and Medici, E. P. (2021). Large wild herbivores slow down the rapid decline of plant diversity in a tropical forest biodiversity hotspot. *J. Appl. Ecol.* 58, 2361–2370. doi: 10.1111/1365-2664.14054

Winck, G. R., Raimundo, R. L. G., Fernandes-Ferreira, H., Bueno, M. G., D'Andrea1, P. S., Rocha, F. L., et al. (2022). Socioecological vulnerability and the risk of zoonotic disease emergence in Brazil. *Sci. Adv.* 8, eabo5774. doi: 10.1126/sciadv.abo5774

Zimmermann, A., Baker, N., Inskip, C., Linnell, J. D. C., Marchini, S., Odden, J., et al. (2010). "Contemporary views of human–carnivore conflicts on wild rangelands," in *Wild Rangelands: Conserving Wildlife While Maintaining Livestock in Semi-Arid Ecosystems*. Eds. J. T. Du Toit, R. Kock and J. C. Deutsch (New Jersey, USA: Blackwell Publishing), 129–151.