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Impact of subsistence hunting on the diversity of wildlife species in the Amazonian Andes of Northeastern Peru

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Abstract. *Coronel-Castro E, Meza-Mori G, Torres-Guzmán C, Oliva-Cruz M, Pariente-Mondragón E, Sopla-Tafur R, Barboza E, Amasifuen Guerra CA. 2024. Impact of subsistence hunting on the diversity of wildlife species in the Amazonian Andes of Northeastern Peru. Biodiversitas 25: 4816-4828.* This study examines the impact of subsistence hunting on wildlife diversity in the northeastern Amazonian Andes of Peru, where hunting is a crucial activity for the food and livelihoods of rural communities. Fieldwork was conducted in 25 communities, where 1,027 residents were interviewed to identify the species hunted, the motivations behind this practice, and the impact of hunting on species population abundance. A total of 53 hunted species were recorded (24 birds and 29 mammals), with notable orders including Carnivora, Columbiformes, and Rodentia. Species diversity was assessed using diversity indices, and community clustering was analyzed, revealing a high diversity of hunted species. In two communities, Omia and Primavera, hunting was fairly evenly distributed among various species. In comparison, in Lonya Grande and Nuevo Tingo, we found a concentration of hunting on a few species, potentially leading to the overexploitation of these populations. Additionally, communities were categorized into two main hunting groups based on ecosystem and elevation. Principal component analysis revealed that species such as *majaz* (*Cuniculus taczanowskii)* and *venado gris* (*Odocoileus virginianus*) are hunted primarily for food, while others, such as *loro choclero* (*Psittacara mitratus*), are hunted for conflict with humans. Moreover, there was a widespread perception of the declining abundance of hunted species, indicating the pressure that subsistence hunting places on local wildlife. These findings highlight the need for collaborative, sustainable management strategies to conserve wildlife in this ecoregion, emphasizing the role of the entire community in this crucial effort.

Keywords: Biodiversity, conflicts, hunting motives, mammals, rural communities

INTRODUCTION

Wildlife plays a fundamental role in the structure and dynamics of ecosystems and is critical for essential ecological processes such as energy flow, seed dispersal, and pollination. Their presence and function within ecosystems not only help maintain environmental stability but are also vital to the livelihoods of diverse human communities (Hernández et al. 2013; Lira-Torres et al. 2014). Wildlife serves as an indispensable resource for multiple aspects of human life, ranging from meeting nutritional and medicinal needs to preserving cultural practices and generating economic income through the trade of animal-derived products (Monroy and García 2013). In this context, hunting emerges as a primary method of exploiting wildlife and plays a crucial role in local economies, especially in regions where hunting is a subsistence activity. This economic role of hunting underscores the significance of wildlife in rural economies, providing a source of income and livelihood for many communities (Francesconi et al. 2018).

Subsistence hunting is of great importance to many rural and traditional communities, providing an important source of food and income. In many regions, wildlife meat is not only an essential part of the diet, but also economically supports household livelihoods, making hunting a vital activity for the survival and economic well-being of these populations (Shoobridge 2019). Moreover, in many cultures, hunting is deeply rooted in traditions and cultural practices, reinforcing its value beyond its purely economic function. This activity is characterized as an adaptive strategy that allows hunters to meet the basic needs of their families and, in some cases, entire communities (Santos-Frita 2013). Importantly, hunting also plays a significant role in social cohesion, strengthening community ties and fostering a sense of shared responsibility and mutual support, thereby contributing to the preservation of traditional knowledge (Maturbongs et al. 2024).

Despite its importance, subsistence hunting poses certain risks to wildlife populations, although these risks are generally lower compared to commercial hunting. On

the other hand, the increasing availability of firearms has intensified hunting and improved hunter strategies (De Souza-Mazurek et al. 2000). This has influenced the increase in wildlife crime worldwide in recent years (Koutchoro et al. 2024). In fact, human activities can determine how animals use the landscape (Mumme et al. 2023; Handschuh et al. 2024). The problem, in some developing countries is serious, as wildlife crime regulations and enforcement are weak (Koutchoro et al. 2024). These regulations propose guidelines for subsistence and sport hunting, however, in practice, they do not officially define hunting seasons, species, or quotas for native wildlife, which promotes the mismanagement of natural resources and wildlife (El Bizri 2024; Koutchoro et al. 2024). This could generate social conflicts and affect economic progress and tourism (Kurland et al. 2017). In addition, illegal wildlife trade can deprive local communities of their livelihoods and increase poverty and inequality (Duffy et al. 2016; Anagnostou et al. 2021).

Research has shown that subsistence hunting can increase pressure on target species, particularly on large and medium-sized vertebrates, which can lead to significant negative impacts on wildlife populations (Benitez-Lopez et al. 2017). Studies such as those by Kirkland et al. (2018) highlight hunting as a significant threat to wildlife, noting that the overexploitation of faunal resources can have negative impacts on both animal populations and human communities that depend on these resources. Harrison et al. (2016) also points out that hunting negatively affects the structure of vertebrate communities, mainly due to the selective and excessive removal of certain species, such as large prey. This phenomenon contributes to the massive population collapse and geographic range reduction of many terrestrial mammals worldwide. Bowyer et al. (2019) highlights that the world's mammals are endangered by hunting, highlighting the urgent need for action to prevent the continued loss of biodiversity.

In Peru, research has been conducted on wildlife hunting in Amazonian communities where the predominant ecosystem is tropical rainforest (Gonzales and Llerena 2014; Pérez-Peña et al. 2023). However, there is a notable lack of kind of studies in rural communities in the Amazonian Andes of Peru, despite the fact that subsistence hunting is a common practice in all rural areas of this country. This gap in scientific knowledge represents an opportunity to explore and document the specific characteristics of hunting in these communities. In this study we find to fill this information gap by documenting the characteristics of hunting in rural communities in the Amazonian Andes of northeastern Peru. The goal of this study is to document the diversity of species hunted and the reasons for this activity, in order to provide a more comprehensive and accurate understanding of its impact on local wildlife and the socioeconomic dynamics of the region.

MATERIALS AND METHODS

Study area

This research was conducted in the Amazonian Andes of northeastern Peru, in a transitional zone that combines both Amazonian and Andean characteristics, differentiated by its ecosystem composition, climate, and topography as a consequence of its location on the eastern flank of the Andes Mountain range (Barboza et al. 2020). Culturally, this region extends from 2,000 to 3,000 meters above sea level (masl) (Kauffmann Doig 1994). Ecologically, however, the Amazonian Andes encompass elevations from 500 to 3800 masl, characterized by the presence of high rainforests with typical Amazonian vegetation, as well as narrow valleys and steep slopes (Young et al. 2015; Chaca and Fernández 2016). This study focused on various rural communities in the Amazonian Andes of northeastern Peru (Figure 1).

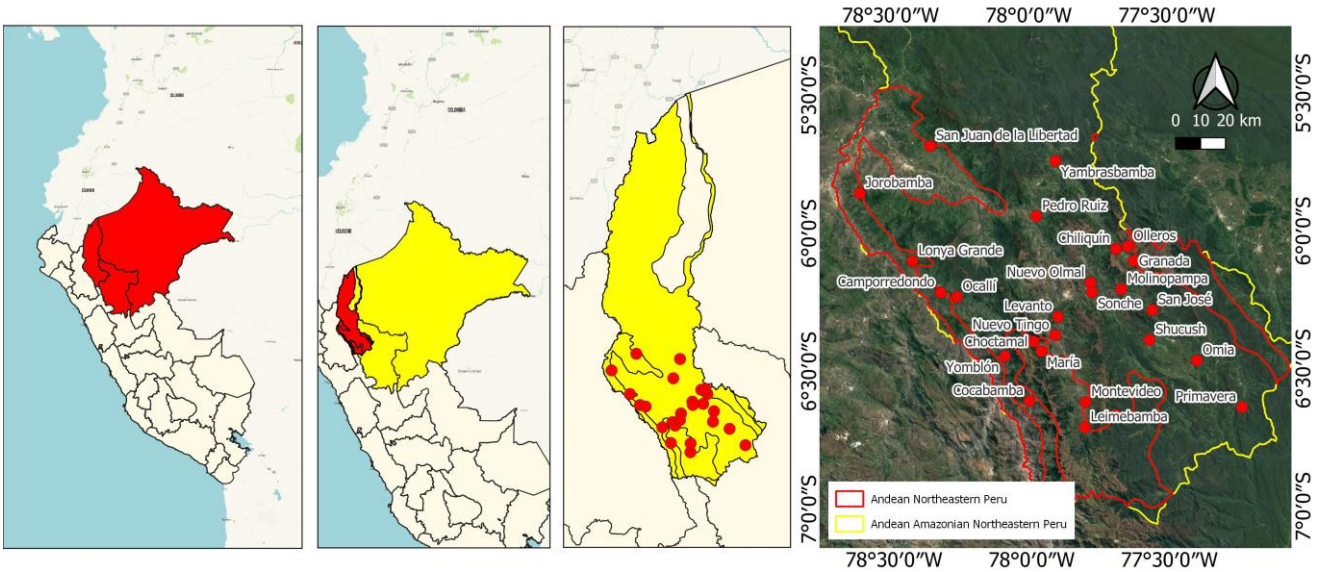

Figure 1. Location of the rural communities of the Amazonian Andes of northeastern Peru

The variation in altitudes and topographic diversity generate a wide range of ecological conditions and soil types, giving rise to different ecological floors, such as high forest (basimontane forest, montane forest and pluvial altimontane forest), and jalca (Ministerio del Ambiente 2017, 2019). However, humid forests mainly characterize this region as a result of intense annual rainfall. In terms of biodiversity, the area is home to a wide variety of fauna, including primates, rodents, felines, birds, reptiles, amphibians, river fish, and a large diversity of insects, as well as a rich flora with an abundance of palms, ferns, and fruit trees (Chaca and Fernández 2016). In Peru, this region covers approximately 208,077.44 km² and is more predominant in the northern departments, such as Amazonas, Cajamarca, Piura and San Martin (Brack 1986; Ministerio del Ambiente 2017).

Field study

This study was based on a field survey applied in several rural communities located in the Amazonian Andes, in the northeastern of the department of Amazonas, Peru. The selection focused on the central and southern areas of the department, where most of the rural communities are concentrated. In order to identify the most representative communities in this region that offered the appropriate conditions to understand hunting practices, several criteria were considered. First, the selected communities are located in ecosystems such as basimontane forest, montane forest, pluvial altimontane forest and jalca, natural areas with remarkable biological diversity (Ministerio del Ambiente 2019; Pronaturaleza 2021). In addition, those with the largest rural population were prioritized (Instituto Nacional de Estadística e Informatica 2018), in order to ensure adequate representativeness of hunting perceptions. Another key criterion was geographic location, choosing communities centrally located in each ecosystem to ensure representativeness. Finally, communities with greater vegetation cover were selected, as a greater expanse of vegetation provides more resources and opportunities for hunting practices (Day Pilaría 2018). A total of 25 communities were selected: Camporredondo, Chiliquín, Choctamal, Cocabamba, Granada, Jorobamba, Leimebamba, Levanto, Lonya Grande, María, Molinopampa, Montevideo, Nuevo Olmal, Nuevo Tingo, Ocallí, Olleros, Omia, Pedro Ruiz, Primavera, San José, San Juan de La Libertad, Shucush, Sonche, Yambrasbamba, and Yomblón (Figure 1). Prior to the application of each survey, verbal consent was obtained from participants, and the ethical guidelines of the International Society of Ethnobiology (International Society of Ethnobiology Code of Ethics 2006; Hassan et al. 2022) was complied with. The survey targeted local residents over 34 years of age, knowledgeable about hunting practices in the region and linked to the rural activities and traditions of their communities. The choice of this age group was based on previous studies indicating that people over 34 years of age perform most of the hunting activity and are more associated with field work and local customs (Anaya-Zamora et al. 2017; Raftogianni et al. 2022).

Respondents were selected by random sampling (García et al. 2018; Hassan et al. 2022), for which the following formula was used to determine the sample size (Montesano 2001):

$$n = \frac{\mathrm{N\ x}\ Z_{\alpha}^{2}\ x\ p\ x\ q}{e^{2}\ x\ (N-1) + Z_{\alpha}^{2}\ x\ p\ x\ q}$$

Where:

n: Sample size

N: Size of the population or universe

Z: Statistical parameter dependent on the confidence level (CL)

e: Maximum acceptable estimation error

p: Probability of occurrence of a studied event (success)

A total of 1,577 residents over 34 years of age were identified, of which 1,366 confirmed to be residents of the rural communities. From this total, a sample of 1,182 people to be surveyed was calculated. However, the final sample consisted of 1,027 participants distributed among the 25 selected communities (Table 1), given that some individuals were unaware of the hunt or decided not to participate in the survey.

Table 1. Determination of the number of people surveyed per rural community in the Amazonian Andes of northeastern Peru

Rural community	Population > 34 years old	Population > 34 years old (resident)	Calculated sample	Final sample
Camporredondo	96	81	67	59
Chiliquín	42	33	30	25
Choctamal	48	40	36	31
Cocabamba	35	27	25	22
Granada	73	62	54	46
Jorobamba	94	83	68	61
Levanto	65	59	51	44
Leimebamba	71	62	54	51
Lonya Grande	102	86	70	58
María	47	43	39	35
Molinopampa	94	76	64	56
Montevideo	33	29	27	22
Nuevo Olmal	39	36	33	31
Nuevo Tingo	58	49	44	34
Olleros	33	30	28	25
Ocallí	73	65	56	46
Omia	69	63	54	45
Pedro Ruiz	93	74	62	49
Primavera	56	50	44	38
San José	68	62	53	53
San Juan de la Libertad	89	78	65	57
Shucush	44	41	37	31
Sonche	24	22	21	21
Yambrasbamba	73	64	55	46
Yomblón	58	51	45	41
Total	1577	1366	1182	1027

Interviews were conducted with residents involved in hunting activities in each location. The selection of these individuals was initially done using the "key informant" technique (García et al. 2018), which involves contacting a community leader, community head, or someone with extensive knowledge and influence within their community. A snowball sampling technique was then used to identify individuals of interest for the research. In this method, one interviewee refers the researcher to another person, who in turn provides the name of a third person, and so on; thus, snowball sampling allows for the identification of initial participants who then refer additional potential respondents (Naderifar et al. 2017; Bula 2023). This collaborative approach ensured that the research was comprehensive and inclusive. However, although the identified hunters provided the requested information, many expressed reluctances to engage in hunting activities for fear of being reported.

Surveys were semi-structured and included questions on species hunted, reasons for hunting, and perceptions of species abundance. This approach is common in studies of subsistence hunting studies and has been documented in previous research (Lira-Torres et al. 2014; García et al. 2018; Hassan et al. 2022; Castillo-Doloriert et al. 2024). In some communities, authorization was obtained to accompany hunters in their activities, allowing photographic capture of the animals hunted in the local forests. In addition, camera traps were placed in the forests near the communities in order to monitor wildlife, which facilitated the identification of the diversity of species hunted. Camera installation was limited to areas adjacent to 13 communities due to limited availability of equipment and lack of permits in some locations. Despite these restrictions, we were able to place the cameras in strategic locations, which made it possible to record the greatest diversity of wildlife.

Species inventory

All species of hunted wildlife, including both birds and mammals, were recorded and documented in terms of orders, families, genera, and species. This documentation was based on the online database "Integrated Taxonomic Information System" (https://www.itis.gov) (accessed 21 May 2024). Taxonomic identification was performed using specialized literature (Schulenberg et al. 2010; Quiñonez and Hernandez 2017; Pacheco et al. 2020, 2021; Salinas et al. 2021), as well as the support of local wildlife experts.

Data analysis

The following parameters were analyzed using RStudio 4.4.1:

Species abundance

The abundance of hunted species was estimated based on local people´s perceptions. This methodology follows established approaches for assessing hunting pressure on biodiversity (Kamgaing et al. 2019).

Alpha diversity

Alpha diversity indices were calculated, including species richness (S), the inverse Simpson Index (1/D), the Shannon-Wiener index (H'), and the Fisher index (α). Communities were compared based on their alpha diversity values to assess variation in species diversity and hunting pressure (Rebollar-Téllez and Moo-Llanes 2020; Keybondori et al. 2023).

Cluster analysis

A cluster analysis was performed to identify patterns in the similarity of hunted species among communities. This analysis is based on the Jaccard similarity index, which ranges from a minimum of zero (completely dissimilar communities) to a maximum of one (identical communities in terms of species presence/absence) (Velamazán et al. 2018; Culqui et al. 2024).

Principal Component Analysis (PCA)

A PCA was used to identify patterns in hunting drivers and to assess the relationship between species abundance and hunting pressure (Hassan et al. 2022; Pérez-Peña et al. 2023). Also, a PERMANOVA was conducted to determine significant differences in species dissimilarity based on hunting drivers and perceived abundance. This method is useful for the analysis of multivariate data (dos Santos Teixeira et al. 2020; Parsons et al. 2022).

RESULTS AND DISCUSSION

Inventory of hunted species

A total of 53 species were recorded, consisting of 24 birds and 29 mammals, distributed in 48 genera, 31 families and 17 orders. The most diverse order in terms of species hunted was Carnivora with 9 species, followed by Columbiformes with 7 species, Rodentia with 6 species, and Artiodactyla and Galliformes with 4 species each. Among the families with the greatest diversity are Columbidae with 7 species, followed by Cracidae with 4 species, and Mustelidae and Ramphastidae with 3 species each. Among the genera, Patagioenas was the most diverse with 4 species, while Dasypus, Didelphis and Psittacara only presented 2 species each (Table 2).

Abundance of hunting species

The most frequently hunted wildlife species in the Amazonian Andes of northeastern Peru, based on the perceptions of local people, are shown in Figure 2. Species such as *Cuniculus taczanowskii*, *Odocoileus virginianus*, *Leptotila verreauxi*, and *Dasyprocta fuliginosa* show the highest frequency of hunting across all communities. In contrast, hunting of *oso perezoso* (*Cyclopes didactylus)*, *puma* (*Puma concolor)*, *lobo de río* (*Lontra longicaudis)*, and *sachavaca* (*Tapirus terrestris)* is infrequent and limited to a few localities, which may be due to factors such as the distribution and/or abundance of the species, given that their recording in the camera traps was rare. Perceptions of local people about the abundance of most hunted species are asymmetrical; some species are heavily hunted in

certain areas, but rarely or not at all in others. Conversely, other species are hunted in several communities, but are perceived to be hunted infrequently in each locality. These latter species include *oso de anteojos* (*Tremarctos ornatus)*, *trigrillo* (*Leopardus pardalis)*, *mono nocturno* (*Aotus miconax)*, *cashapicuro* (*Coendou bicolor)*, *achuni (Nasua nasua)*, *ardilla* (*Sciurus spadiceus)*, *Caracara* (*Daptrius megalopterus)*, *Gavilán* (*Falco sparverius)*, *Zorzal* (*Turdus fuscater)*, *Garza de río* (*Nycticorax nycticorax)*, and *tucán de garganta amarilla* (*Ramphastos ambiguus)*, which are hunted primarily because of conflicts with local people and/or incidental encounters in the forest or on private land.

The range-abundance curve showing local perceptions of hunted species, arranged in descending order (Figure 3), highlights the ten most commonly reported species. A total of 965 respondents indicated that *Cuniculus taczanowskii* is hunted in the northeastern Andes of Peru. Other commonly hunted species, according to the number of respondents, are *Odocoileus virginianus* (958), *Leptotila verrauxi* (913), *Dasyprocta fuliginosa* (803), *Penelope montagnii* (792), *Psittacara mitratus* (707), *Silvilagus andinus* (476), *Nothoprocta pentlandii* (437), *Dasypus novemcinctus* (397), and *Patagioenas fasciata*.

Table 2. Wildlife hunted in rural communities in the Amazonian Andes of northeastern Peru

Class: Order: Family: Species	Common name
Aves: Columbiformes: Columbidae	
Leptotila verreauxi Bonaparte	*Paloma, pugo*
Patagioenas cayannensis Bonnaterre	*Luta, turca, torcaza*
Patagioenas fasciata Say	*Luta, paloma de nuca blanca, turca, torcaza*
Patagioenas oenops Linnaeus	*Turca, torcaza*
Patagioenas subvinacea Lawrence	*Turca, torcaza*
Zenaida auriculata Des Murs	*Tórtola, saparcita*
Zentrygon frenata Tscudi	*Paloma de montaña*
Aves: Falconiformes: Falconidae	
Daptrius megalopterus Meyen	*Caracara, aguila negra*
Falco sparverius Linnaeus	*Gavilán*
Aves: Galliformes: Cracidae	
Aburria aburri Lesson	*Pava curunculada, pava negra*
Chamaepetes goudotii Lesson	*Pava grande, Sachahuashpa*
Ortalis guttata Spix	*Guataraco*
Penelope montagnii Bonaparte	*Columcha, pava mora, pisha, sachahuashpa tataca*
Aves: Passeriformes: Cardinalidae	
Pheucticus chrysogaster Lesson	*Piuro*
Aves: Passeriformes: Corvidae	
Cyanocorax yncas Boddaert	*Quinquin, quienquién*
Aves: Passeriformes: Turdidae	
Turdus fuscater Lafresnaye & D´Orbigny	*Sorzal*
Aves: Pelecaniformes: Ardeidae	
Nycticorax nycticorax Linnaeus	*Garza de río*
Aves: Piciformes: Ramphastidae	
Andigena hypoglauca Gould	*Tucán pechigrís*
Ramphastos ambiguus Swainson	*Tucán de garganta amarilla*
Selenidera reinwardtii Wagler	*Tucancito de pico rojo*
Aves: Psittaciformes: Psittacidae	
Psittacara mitratus Tscudi	*Loro choclero, loro cabeza roja*
Psittacara sp.	*Loro upa*
Aves: Tinamiformes: Tinamidae	
Crypturellus obsoletus Temmynck	*Perdíz marrón, perdíz grande*
Nothoprocta pentlandii Gray	*Perdiz, perdiz pequeña*
Mammalia: Artiodactyla: Cervidae	
Mazama americana Erxleben	*Venado colorado*
Odocoileus virginianus Zimmermann	*Venado gris*
Mammalia: Artiodactyla: Tayissuidae	
Dicotyles tajacu Linnaeus	*Sajino*
Tayassu pecari Link	*Huangana*
Mammalia: Carnivora: Canidae	
Lycalopex culpaeus Molina	*Zorro*
Mammalia: Carnivora: Filidae	
Leopardus pardalis Linnaeus	*Chinchay, tigrillo*
Puma concolor Linnaeus	*Leonera, puma*
Mammalia: Carnivora: Mephitidae	
Conepatus semistriatus Boddaert	*Zorrillo*
Mammalia: Carnivora: Mustelidae	
Eira barbara Linnaeus	*Tayra, tejón*
Lontra longicaudis Olfers	*Lobo de río, nutria*
Mustela frenata Illiger	*Guaygash, guaygashillo*
Mammalia: Carnivora: Procyonidae	
Nasua nasua Linnaeus	*Achón, achuni*
Mammalia: Carnivora: Ursidae	
Tremarctos ornatus Cuvier	*Oso de anteojos, oso andino*
Mammalia: Cingulata: Dasypodidae	
Dasypus novemcinctus Linnaeus	*Armadillo, Carachupa*
Dasypus pilosus Fitzinger	*Amadillo peludo, carachupa peluda*
Mammalia: Didelphimorphia: Didelphidae	
Didelphis marsupialis Linnaeus	*Canchul, chepa, sarihueya*
Didelphis pernigra Allen	*Canchul, chepa, sarihueya*
Mammalia: Lagomorpha: Leporidae	
Sylvilagus andinus Thomas	*Conejo*
Mammalia: Perissodactyla: Tapiridae	
Tapirus terrestris Linnaeus	*Sachavaca*
Mammalia: Pilosa: Cyclopedidae	
Cyclopes didactylus Linnaeus	*Oso perezoso*
Mammalia: Primates: Aotidae	
Aotus miconax Thomas	*Mono nocturno*
Mammalia: Primates: Atelidae	
Ateles belzebuth É. Geoffroy	*Maquizapa*
Mammalia: Primates: Cebidae	
Saimiri cassiquiarensis Lesson	*Mono ardilla*
Mammalia: Rodentia: Caviidae	
Cavia tschudii Fitzinger	*Cuy salvaje, sachacuy*
Mammalia: Rodentia: Cuniculidae	
Cuniculus taczanowskii Stolzmann	*Majás, picuro*
Mammalia: Rodentia: Dasyproctidae	
Dasyprocta fuliginosa Wagler	*Añuje, chosca*
Mammalia: Rodentia: Dinomydae	
Dinomys branikii Peters	*Picuro mama, ronsoco*
Mammalia: Rodentia: Erethizontidae	
Coendou bicolor Tschudi	*Cashapicuro, puercoespín*
Mammalia: Rodentia: Sciuridae	
Sciurus spadiceus Olferes	*Ardilla*

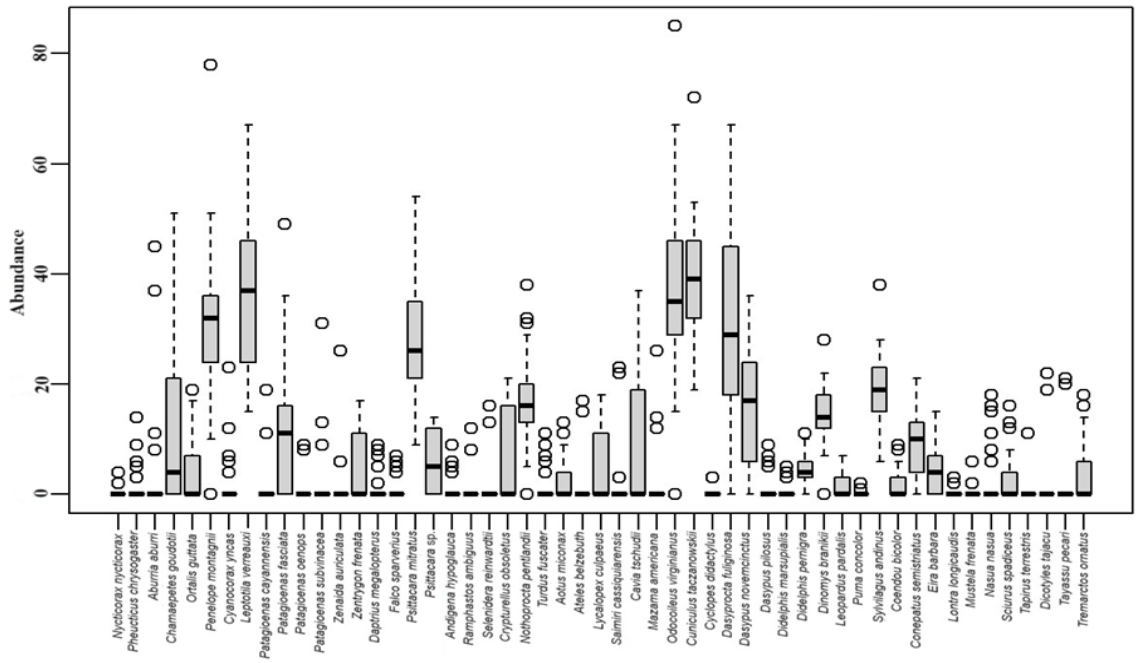

Figure 2. Perception of wildlife hunting abundance in the Amazonian Andes of northeastern Peru. The midline indicates the median, the box is the interquartile range, and the black circles are outliers

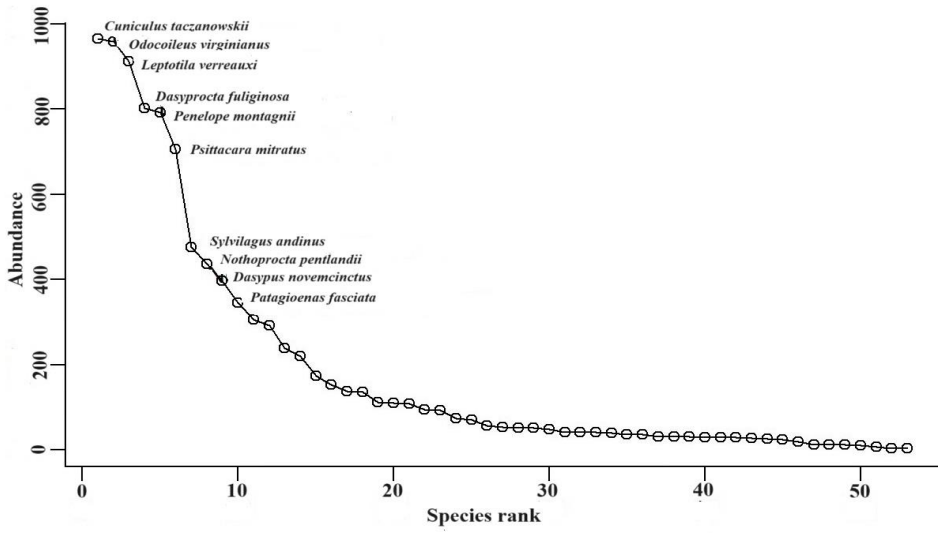

Figure 3. Distribution-abundance curve of hunted species as perceived by local people in the Amazonian Andes of northeastern Peru

Diversity indices of hunted species

The values obtained for alpha diversity, i.e., the number of species present in each community (specific richness (S)) and the indices based on the structure within each community (inverse Simpson index (1/D), Shannon-Wiener index (H´) and alpha Fisher index (α) are shown in Table 3.

The communities of Omia, Primavera and San José have the highest number of species hunted and the highest values of the inverse Simpson index, the Shannon-Wiener index and the Fisher index, indicating a high diversity of species hunted in these localities. Nevertheless, hunting is balanced and infrequent for most species. Similarly, in Molinopampa, María, Leimebamba, and Levanto, a high number of hunted species and high values of the diversity indices are observed, indicating an equitable distribution of hunting among different species, without any species being hunted predominantly. In Sonche, the high values of the inverse Simpson index and the alpha Fisher index also reflect a high diversity of hunted species. However, of most species is rare or unusual. On the other hand, Lonya Grande, Nuevo Tingo and Olleros show lower values of richness and diversity, indicating a lower diversity of hunted species and a more concentrated hunting of certain species.

Similarity of hunted species among communities

Clustering analysis based on hunted species similarity in rural communities in the Amazonian Andes of northeastern Peru revealed two main groups with approximately 70% overlap (Figure 4). The first group includes Omia, Primavera, San Juan de la Libertad, Yambrasbamba, Shucush, Camporredondo, Ocallí, María, Choctamal, Yomblón, San José, Molinopampa, Leimebamba, and Levanto. Within this group, the first seven localities form a subgroup characterized by hunting areas located mainly in the basimontane forests. The second subgroup includes the remaining communities located in the montane forests and the pluvial altimontane forests. The second group consists of Nuevo Olmal, Sonche, Nuevo Tingo, Pedro Ruiz, Cocambamba, Chiliquín, Granada, Montevideo, Olleros, Jorobamba and Lonya Grande. The similarity in species composition among these communities can be attributed to their common ecosystems. Some of these communities, such as Nuevo Olmal, Sonche, Nuevo Tingo, Pedro Ruiz, Cocambamba, Montevideo, Jorobamba and Lonya Grande, are located near dry forests. In comparison, Chiliquín, Granada and Olleros are located in the jalca.

Grouping of hunted species

Principal component analysis was used to group the 10 most hunted species according to the reasons for hunting in the study communities (Figure 5). The species *Penelope montagnii*, *Odocoileus virginianus*, *Patagioenas fasciasta*, *Cuniculus taczanowskii*, *Leptotila verreauxi*, *Dasyprocta fuliginosa*, *Dasypus novemcinctus* and *Sylvilagus andinus* were found to be hunted mainly for food consumption by the inhabitants of the Amazonian Andean communities of northeastern Peru (Figure 6). In contrast, *Psittacara mitratus* and *Nothoprocta pentlandii* are hunted mainly for the conflicts they cause by damaging crops. Hunting for commercial purposes, such as pets or medicine, is irrelevant or rare in these communities. Significant differences in dissimilarity were identified using PERMANOVA with a p-value of 0.0001.

Table 3. Richness values and alpha diversity indices of wildlife species hunted by rural communities in the Amazonian Andes of northeastern Peru

Community	S	1/D	H´	α
Camporredondo	19	12.87	2.70	3.97
Chiliquin	18	13.91	2.74	4.08
Choctamal	20	13.46	2.74	4.78
Cocabamba	18	14.30	2.75	4.52
Granada	19	14.37	2.78	3.94
Jorobamba	17	11.68	2.60	3.34
Leimebamba	26	18.12	3.06	5.82
Levanto	25	17.98	3.04	5.76
Lonya Grande	13	9.87	2.39	2.54
María	26	19.04	3.07	6.15
Molinopampa	30	15.55	3.02	6.40
Montevideo	17	12.83	2.67	4.29
Nuevo Olmal	21	13.91	2.79	5.09
Nuevo Tingo	13	9.45	2.39	3.09
Ocallí	19	13.17	2.71	4.13
Olleros	14	11.01	2.48	3.28
Omia	34	22.59	3.28	7.82
Pedro Ruiz	16	10.09	2.45	3.54
Primavera	31	24.24	3.29	7.30
San José	30	17.26	3.07	6.75
San Juan de la Libertad	17	11.60	2.59	3.44
Shucush	16	11.30	2.55	3.65
Sonche	24	15.33	2.89	6.69
Yambrasbamba	21	12.82	2.72	4.77
Yomblón	19	14.43	2.80	4.55

Note: S: Species richness, 1/D: Inverse Simpson index, H': Shannon-Wiener index; α: Fisher index

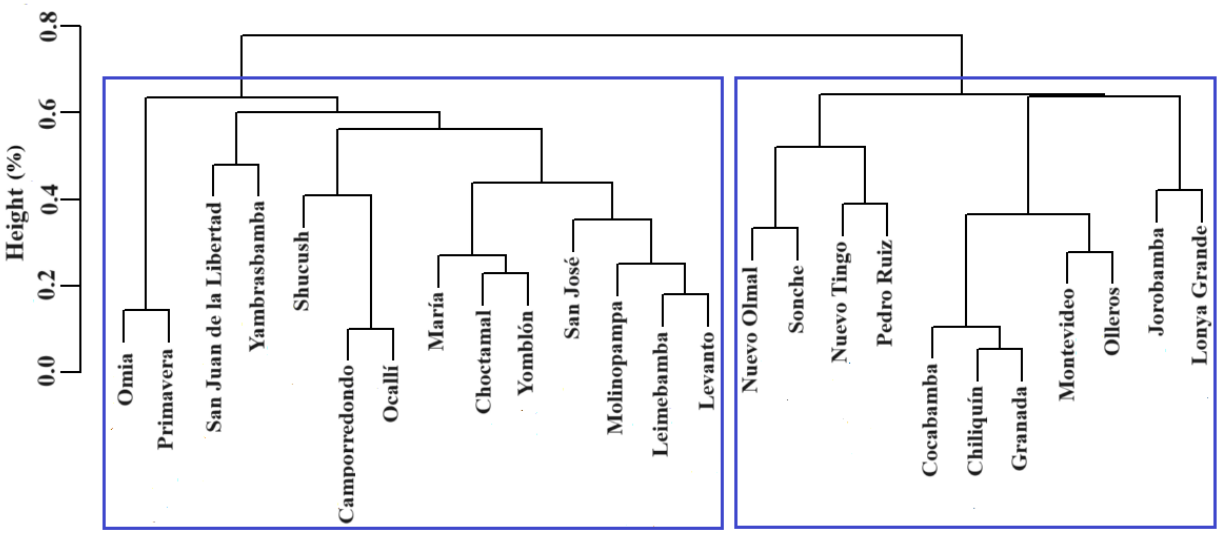

Figure 4. Analysis of the grouping of rural communities in the Amazonian Andes of northeastern Peru, in relation to the species hunted

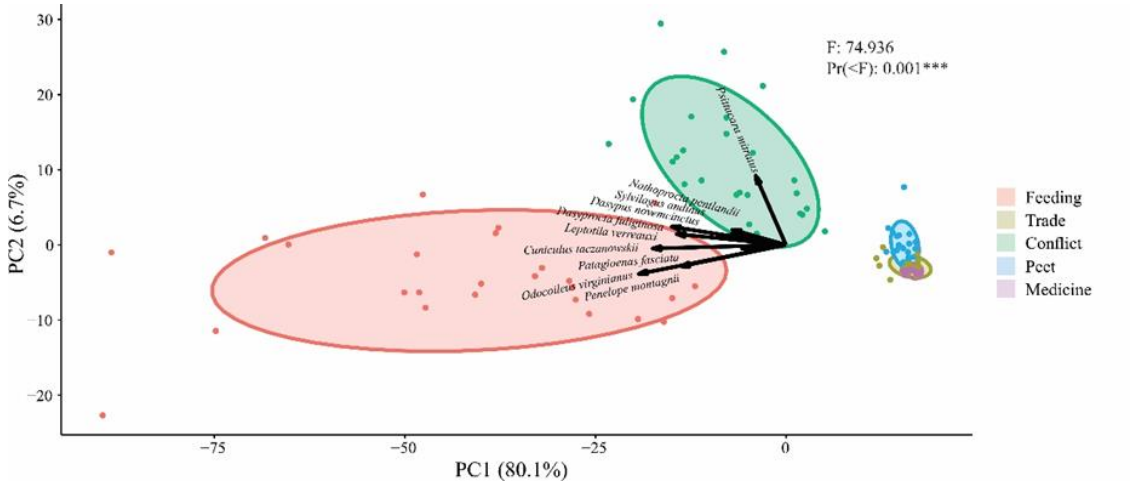

Figure 5. Principal component analysis to group the most hunted species in the Amazonian Andes of northeastern Peru, using the hunting method

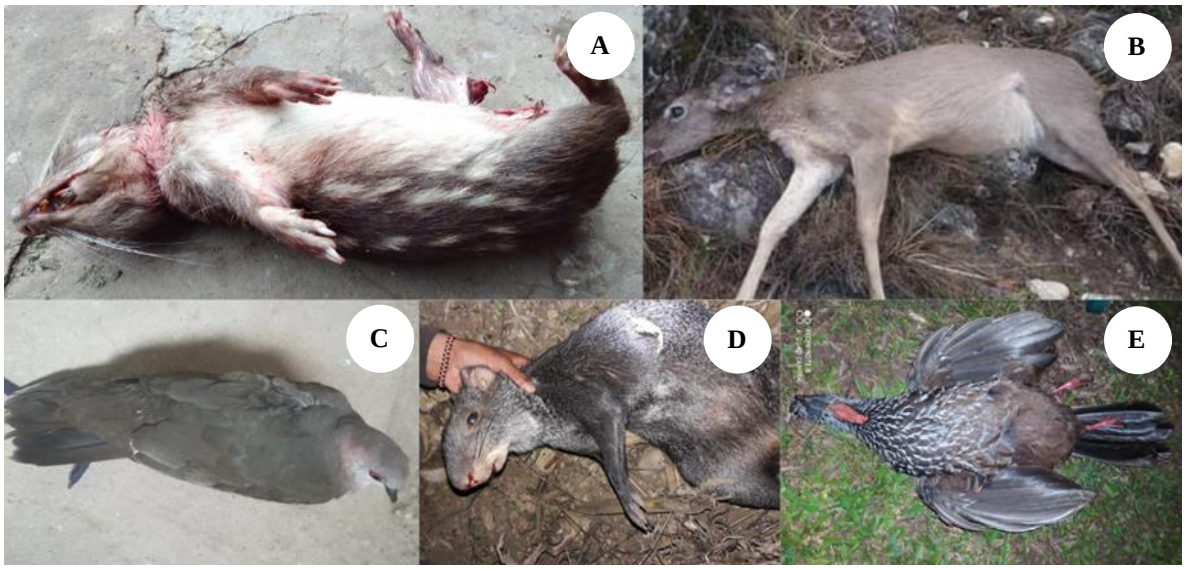

Figure 6. Wildlife hunted for food by communities in the Amazonian Andes of northeastern of Peru

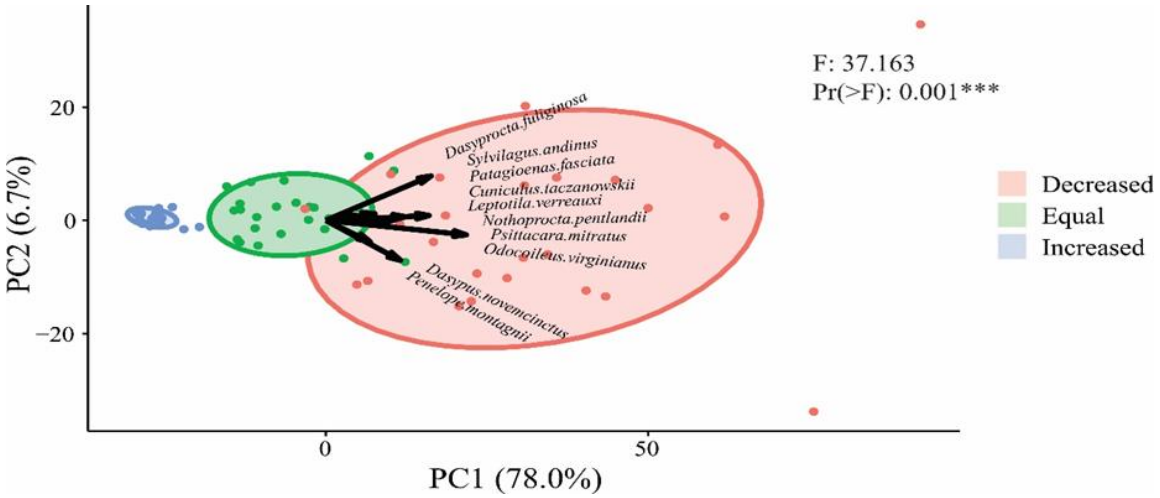

Figure 7. Principal component analysis to group the most hunted species in the Amazonian Andes of northeastern Peru, by means of population abundance perception

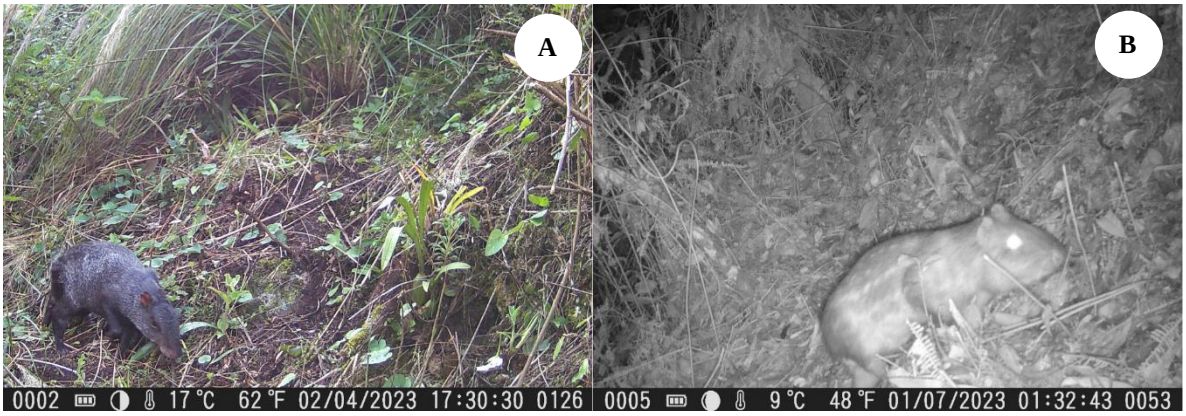

Figure 8. Camera traps recording *Dasyprocta fuliginosa* and *Cuniculus taczanowskii* individuals near crops

Impact of hunting on wildlife populations

A principal component analysis also established a relationship between the 10 most hunted species and the perceived abundance of their populations. This analysis revealed that, in general, respondents believe that the abundance of these species has decreased, with the exception of *Penelope montagnii*, whose population is not perceived as reduced by some residents. Overall, the study indicates that the abundance of these species has not increased in the northeastern Peruvian Amazon Andes, and the PERMANOVA analysis showed significant differences in abundance dissimilarity (Figure 7).

Discussions

The analysis of the diversity of hunted wildlife species in the northeastern Andes of Peru provides a complex outline that integrates both the biological richness of the region and the sociocultural dynamics that influence wildlife hunting practices. The identification of 53 species distributed in 48 genera, 31 families, and 17 orders highlights the remarkable biodiversity of the area and the multiple interactions between human communities and local fauna, as also reported in previous studies in the Amazon region (Gonzales and Llerena 2014; Carignano Torres et al. 2021; Pérez-Peña et al. 2021, 2023). The predominance of species of the order Carnivora, such as the *Puma concolor* and *Tremarctos ornatus* reveals the close coexistence between the local population and these mammal carnivores. Although the hunting of these species is perceived as rare by the local people, it may be associated with human-wildlife conflicts, as these carnivores may pose a potential threat to livestock or agroecosystems. Local perceptions indicate that hunting of large carnivores is rare highlighting the importance of these animals in local culture, and the potential tensions in their management (Zug 2018). On the other hand, the most commonly hunted species belong to the orders Rodentia (mammals) and Columbiformes (birds). These species are primarily hunted for food, although they are also considered agricultural pests due to the damage they cause to crops (Figure 8). This duality in the perception of hunted species suggests a delicate balance between food needs and agricultural conflicts, a situation also observed in other parts of the Amazon (Francesconi et al. 2018) and various regions of the Neotropics (De Souza et al. 2018; Ríos et al. 2018; Castillo-Doloriert et al. 2024).

Alpha diversity indices applied to hunted species in the northeastern Andes of Peru reveal significant variability. The communities of Omia, Primavera, and San José exhibit high species richness and diversity. These findings suggest that hunting in these communities is evenly distributed among a wide variety of species, which may be related to sustainable hunting strategies or a traditional use of the natural environment that supports local biodiversity conservation (Neumann et al. 2022). Despite the high diversity, the perception of hunting frequency is generally low, suggesting that pressure on animal populations may be manageable; however, emphasize the need for monitoring these practices to ensure long-term sustainability. In contrast, the communities of Lonya Grande, Nuevo Tingo, and Olleros greater concentration of hunting is perceived in a few species, such as *Cuniculus taczanowskii*, *Odocoileus virginianus*, *Dasyprocta fuliginosa*, and *Leptotila verreauxi*. This specialization in certain species could lead to overexploitation, a worrying pattern observed in other rural areas of Latin America (Solano-Gómez and Mora 2023). Selective pressure can lead to local declines of key species, affecting the stability of ecosystems and the environmental services they provide (Nešić and Bjedov 2020).

Cluster analysis of communities reveals the influence of shared ecosystems on the similarity of hunted species across communities, highlighting how habitat characteristics determine hunting dynamics (Nasi et al. 2011). Specifically, communities with higher species richness and diversity of hunted species are located in the Yunga montane forest, montane forest, and altimontane forest. This suggests that the high hunting indices in these areas may be related to the specific ecological characteristics and species availability in these habitats. In contrast, communities near dry forests and those above 2,900 masl, where grasslands and shrubs predominate, have a lower diversity of hunted species due to the reduced variety of wildlife available in these environments.

Principal component analysis of hunted species and reasons for hunting reveals a clear distinction between

hunting for subsistence and hunting driven by conflict, such as crop damage. These findings are consistent with previous studies documenting that hunting in rural communities is often focused on species that provide essential food resources. In comparison, other species are hunted as a means of crop damage control (Coad et al. 2019). Furthermore, in terms of the abundance of the species being hunted, respondents' perceptions of declining abundance are significant, despite the relatively low frequency and pressure of hunting. This may indicate that subsistence hunting, even at low levels, can have significant negative impacts on wildlife, particularly medium and large sized mammals, as noted in previous studies (Francesconi et al. 2018; McFarlane et al. 2024). The impact of subsistence hunting on wildlife in the Amazonian Andes highlights the need for sustainable management of these practices. While not the primary driver of biodiversity loss, these activities can contribute to the decline of certain species if not managed appropriately. Subsistence hunting is a crucial means of survival for many rural and indigenous communities, particularly in areas where other sources of income or food are limited. In these contexts, hunting is not only an economic activity, but a way to ensure food security (Francesconi et al. 2018; Suarez and Zapata-Ríos 2019; Gilmore et al. 2020; Ingram et al. 2021). According to the FAO report (2020), millions of people depend on hunting to obtain essential proteins and nutrients in rural areas, especially in places where agriculture is not viable due to climatic or geographical factors. Therefore, imposing restrictions on this activity can jeopardize the subsistence and well-being of rural and indigenous communities (Blackie 2019), and the sustainable conservation of wildlife species (Santos-Fita 2018). However, Law 29763 (SERFOR 2015) and its regulations in Peru allow subsistence hunting in rural and indigenous communities, where communal authorities must be in charge of regulating and managing the use of wildlife species based on the number of inhabitants, area of the community and wildlife conservation status, respecting regulations on endangered species and ensuring the conservation of the resource, establishing a list of species that can be used for hunting for domestic consumption, setting seasons and quotas. In the case of rural residents who are not part of rural and indigenous communities, subsistence hunting is carried out in areas authorized by the regional authority. Rather than seeking to eliminate hunting of wild animals, the challenge must lie in balancing the need to conserve biodiversity with the social and economic realities of rural communities; Within this problem, properly regulated subsistence hunting can be an efficient alternative both ecologically (control of wildlife species populations) and social (Petriello and Stronza 2019; Suarez and Zapata-Ríos 2019; Gilmore et al. 2020).

On the other hand, the ecological impact of subsistence hunting, although often perceived as minimal compared to global threats such as habitat loss and climate change, can have significant consequences in certain ecological and social contexts. While urbanization, deforestation and climate change are undoubtedly major factors affecting biodiversity, subsistence hunting can intensify these effects in local ecosystems, particularly those where species face additional pressure due to habitat fragmentation (Guzman et al. 2022; Barboza et al. 2024; Vera et al. 2024). Moreover, the interaction of these threats can reduce the resilience of wild populations, underscoring the importance of approaching conservation from a holistic perspective. This involves not only protecting habitats and mitigating climate change, but also ensuring that hunting practices are sustainable (Linares et al. 2024; Sánchez-García et al. 2024). Given the complexity of factors affecting hunting and biodiversity in the Amazonian Andes, effective and adaptive management is needed, which should include environmental education, enforcement of hunting regulations and promotion of sustainable alternatives. This is to balance human needs with the long-term preservation of biodiversity. These conservation strategies should integrate local knowledge and cultural practices to balance human needs with biodiversity conservation (Golebie et al. 2022). In addition, implementation of ongoing biodiversity and game monitoring programs can help identify emerging trends and adjust management strategies in a timely manner. However, the key to success lies in the collaboration between scientists, local authorities and communities is not only essential, but is the cornerstone of our collective effort to develop and implement management practices that are effective and culturally acceptable, thus ensuring the sustainability of natural resources in this biodiversity-rich region of Peru. In addition, it is important to explore complementary alternatives, such as the implementation of community gardens, aquaculture systems, and food assistance programs that strengthen food security. For future studies, it is recommended to conduct a more detailed analysis of the impact of hunting on the population dynamics of these species over time, as well as to investigate livelihood alternatives that could reduce hunting pressure on the most affected species. In addition, it is essential to explore the relationship between hunting and socioeconomic and cultural factors in order to develop conservation strategies that are socially inclusive and sustainable.

In conclusion, the impact of subsistence hunting on wildlife species diversity in the Amazonian Andes of northeastern Peru identified a total of 53 species hunted in 25 communities. The population's perception of hunting varied by species; some were hunted exclusively in specific communities, while others were hunted in all the communities studied. In addition, certain species groups were hunted due to conflicts with the local population or incidental encounters in the forest or on the land. Specifically, *Cuniculus taczanowskii*, *Odocoileus virginianus* and *Leptotila verrauxi* emerged as the most hunted species in the study area. At the community level, Omia, Primavera, San José, Molinopampa, María, Leimebamba and Levanto were identified as having the greatest diversity and number of species hunted. This study is important because it provides fundamental information on the diversity of species affected by subsistence hunting and how this activity reflects the interactions between local people and wildlife.

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