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**Inventory**

# Living at the top of the forest line: medium and large mammals in a high-mountain ecotone in Peruvian Central Andes

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***Abstract:*** Among the ecoregions that comprise the high-Andean zone of the Tropical Andes, the Puna and the Yungas stand out for covering a large part of the Peruvian Eastern Andes. Located in the ecotone of these two ecoregions, the Pampa Hermosa National Sanctuary (PHNS) houses one of the priority areas for conservation in Peru. However, the biodiversity of the high-Andean zone of the sanctuary and its surroundings remains poorly studied. Thus, through camera traps and transects, we sought to inventory for the first time the medium and large mammals from the high-Andean region of the PHNS and its buffer zone. We recorded 11 native and three domestic species of medium and large mammals. The richness of native mammals sampled reached 91.7% of the estimated richness (S est.= 11.99 ± 1.85). Among the native species *Odocoileus virginianus* had the highest relative frequency (56%). We recorded three endemic mammals from the Tropical Andes, *Cuniculus taczanowskii*, *Tremarctos ornatus*, and *Pudu mephistopheles*. The observed richness was higher than most surveys of medium and large mammals carried out in the Puna-forest ecotone in Peru, where the reported richness ranged from 4 to 13 species. In addition, our records of *Leopardus pardalis* and *Eira barbara* are the highest for all distribution of these two carnivores. Our results showed that more than 90% of the species recorded were found in it, demonstrating that the entire high-Andean region of the PHNS and its surroundings has an important value for the local mammal community.
***Keywords:*** *Camera-trap; Eira barbara; Leopardus pardalis; Odocoileus virginianus; Puna; Tropical Andes.*

## Vivendo no topo da linha florestal: mamíferos de médio e grande porte em um ecótono alto-montano nos Andes Centrais Peruanos

***Resumo:*** Dentre as ecorregiões que compreendem a zona alto-andina dos Andes Tropicais, a Puna e as Yungas se destacam por abranger grande parte dos Andes Orientais peruanos. Localizado no ecótono entre estas duas ecorregiões, o Santuário Nacional Pampa Hermosa (SNPH) abriga uma das áreas prioritárias para conservação no Peru. No entanto, a biodiversidade da zona alto-andina do santuário e seu entorno permanece pouco estudada. Dessa forma, através de armadilhas fotográficas e transectos, buscamos inventariar pela primeira vez os mamíferos de médio e grande porte da região alto-andina do SNPH e de sua zona de amortecimento. Nós registramos 11 espécies nativas e três espécies domésticas de mamíferos de médio e grande porte. A riqueza observada dos mamíferos nativos atingiu 91,7% da riqueza estimada (S est.= 11,99 ± 1,85). Dentre as espécies nativas, *Odocoileus virginianus* foi a que apresentou a maior frequência relativa (56%). Registramos três mamíferos endêmicoss dos Andes Tropicais, *Cuniculus taczanowskii*, *Tremarctos ornatus*, e *Pudu mephistopheles*. A riqueza observada foi superior que a maioria dos levantamentos de mamíferos de médio e grande porte feitos em ecótono Puna-bosque no Peru, onde a riqueza reportada variou de 4 a 13 espécies. Além disso, os registros de *Leopardus pardalis* e *Eira barbara* são os mais elevados para toda distribuição destes dois carnívoros. Nossos resultados demonstraram que mais de 90% das espécies registradas foram encontradas nela, demonstrando que toda região alto-andina do SNPH e seu entorno tem um importante valor para a fauna de mamíferos local.
***Palavras-chave:*** *Andes Tropicais; Armadilhas fotográficas; Eira barbara; Leopardus pardalis; Odocoileus virginianus; Puna.*

## Introduction

Peru is considered as one of the most megadiverse countries in the world (Noss 1990, Shanee et al. 2017) and much of this biological diversity is due to the climatic and geographic influence created by the Andes Mountains and the Humboldt Maritime Current (Fajardo et al. 2014). The diversity of ecosystems and habitats created by these factors give rise to a scenario where the neotropical fauna finds countless opportunities for speciation and radiation (Pacheco et al. 2009).

Among the countries with the greatest diversity of mammals, Peru is in the fourth place, with 569 species (Pacheco et al. 2020), only behind Brazil within the neotropical region (SERFOR 2018). Of the 10 large ecoregions existing in Peru (Brack-Egg 1986), the Selva Baixa and the Yungas (or Selva Alta) have the highest rates of mammalian diversity and endemism, respectively (Pacheco et al. 2009). However, with a significant mammal diversity (63 spp.) (Pacheco et al. 2009), the Puna is the dominant ecoregion of the Peruvian high-Andean zone, rising from 3,000-3,500 m to 4,500-5,000 m (Rolando et al. 2017). The Puna is characterized by high-altitude grasslands, and it is subdivided into two ecosystems based on rainfall: (1) Dry Puna, which spans the high plateaus of southern Peru; and (2) Wet Puna, which is found from the center-south to the center-north of the Peruvian Andes (Josse et al. 2009). In the ecotone regions between the Wet Puna and the Cloud Forests of Yungas, a long transition zone is formed between grassland and forest environments, where there is a great sharing of the native fauna and flora of these two ecoregions (Simpson 1983, Buytaert et al. 2011).

Because they are regions with extremely rugged terrain, adverse climatic conditions, and difficult access (Jiménez et al. 2010), these high-Andean zones of the Peruvian Eastern Andes are poorly studied (Pacheco et al. 2009, Medina et al. 2012) and, consequently, the status of biological diversity remains with several local gaps in most of these Andean areas. In this sense, the Protected Areas are essential tools for the conservation of this Andean biodiversity to be explored and, therefore, have a fundamental role in the scientific and ecological development of the country (Shanee et al. 2017, Bax & Francesconi 2019).

In the Peruvian Andes only 36% of the biological diversity existing is protected by the Protected Areas system (Fajardo et al. 2014). This becomes even more worrying given the fact that Peru is the country with the largest extension of the Tropical Andes, one of the main hotspots of global biodiversity and holder of the highest rate of endemism in the world (Myers et al. 2000, Josse et al. 2011).

Located in the Peruvian Central Andes, the Pampa Hermosa National Sanctuary (PHNS) houses an important transitional area of the Puna and Yungas ecoregions of the department of Junín (SERNANP 2012). Despite being considered a priority area for the conservation of Andean-Amazonian biodiversity (SERNANP 2009, 2012, Arias et al. 2016), few expeditions sought to systematically inventory the local biological diversity, especially in the high-Andean zone (> 2,500 m) from the sanctuary, due to its difficult access. Historically, the fauna of the region was first studied in the mid-19th century by naturalist Johann Jakob von Tschudi in the Montaña de Vitoc (Tschudi, 1844a, 1844b). In this pioneering expedition, fish, amphibians, reptiles, birds and mammals were collected (Serrano-Villavicencio et al. 2020), mainly in the Yungas ecoregion, about 20km away from the PHNS. In the recent decades, among the groups already systematically inventoried in the PHNS and its surroundings, there are insects, birds (Silva et al. 2016), bats (Arias et al. 2016) and plants (La Torre-Cuadros et al. 2007, Silva et al. 2016). However, all these surveys were carried out in the lower part (< 2,000 m) of the sanctuary and its buffer zone.

Thus, the biodiversity of the high-Andean zone of the sanctuary and its surroundings remains poorly studied, especially with regard to the terrestrial mammals community. In the PHNS buffer zone , there are several reports of conflict between the communities in the San Pedro de Churco village and the Andean bear (*Tremarctos ornatus*) (Rojas-Vera Pinto & Butrón 2016, Rojas-Vera Pinto 2019), signaling the presence of important endangered species in the sanctuary area. For this reason, in this present study, we sought to inventory, for the first time, the medium and large mammals from the high-Andean zone of the PHNS and its buffer zone. In addition, we compared our observed richness with that of other surveys carried out in similar altitudinal ranges in the Peruvian Eastern Andes.

## Material and Methods

### *1. Study area*

The study was carried out in the PHNS (75º35'09" - 75º24'43"W; 10º58'53" - 11º06'30"S) and in its buffer zone, concentrating on the west side of sanctuary, where the S.P. Churco village (75º33'24"W; 11º02'13"S) is located (Figure 1). The site is situated on the eastern flanks of the Tropical Andes, in the department of Junín, central Peru (SERNANP 2012). The area of the PHNS is 11,543 ha and its buffer zone is 20,292 ha, totaling 31,835 ha of direct and indirect protection of the Andean-Amazonian Peruvian mountain ecosystems along a wide altitudinal range (1,130 to 4,080 m) (SERNANP 2012). The study area was concentrated in the high-Andean zone of the sanctuary and its surroundings, covering an area of approximately 2,500 ha, between 3,200 and 3,700 m.

The study area is located in an ecotone, where two ecosystems belonging to distinct ecoregions are found (Pulgar-Vidal 1987): (1) the Wet Puna of the Puna ecoregion, extending from 3,250 to 5,000 m, characterized by high-Andean grasslands with herbaceous-shrubby vegetation padded with mosses and grasses arranged in clumps (Brack 1986, López 2010) and; (2) the Cloud Forests (or High-Montane Forests) of the Yungas ecoregion, present from 2,500 to 3,300 m, with dense, steep forest vegetation and with a great abundance of epiphytes (Pulgar-Vidal 1987, SERNANP 2012).

The climate of the PHNS and its buffer zone presents a gradual variation along its altitudinal ranges (Junquas et al. 2018, Eghdami & Barros 2019). The highest part of the sanctuary where the Wet Puna and the S.P. Churco village are located corresponds to the climate of High-Montane Dry Tundra (ETH) according to Köppen (1936) (SERNANP 2012). The average annual precipitation varies from 2,000 to 3,000 mm, with greater concentration in the summer and with an average annual temperature of 6 to 10ºC (Yarupaitan & Giraldo 2007, SERNANP 2012). As the altitude decreases to 2,600 m, there is a zone that comprises, the Continental Humid Boreal (Dwb) climate (Köppen 1936). This range also presents low average annual temperatures, ranging from 10 to 12ºC and high average annual precipitation between 3,000 and 4,000 mm (SERNANP 2012, Eghdami & Barros 2019).

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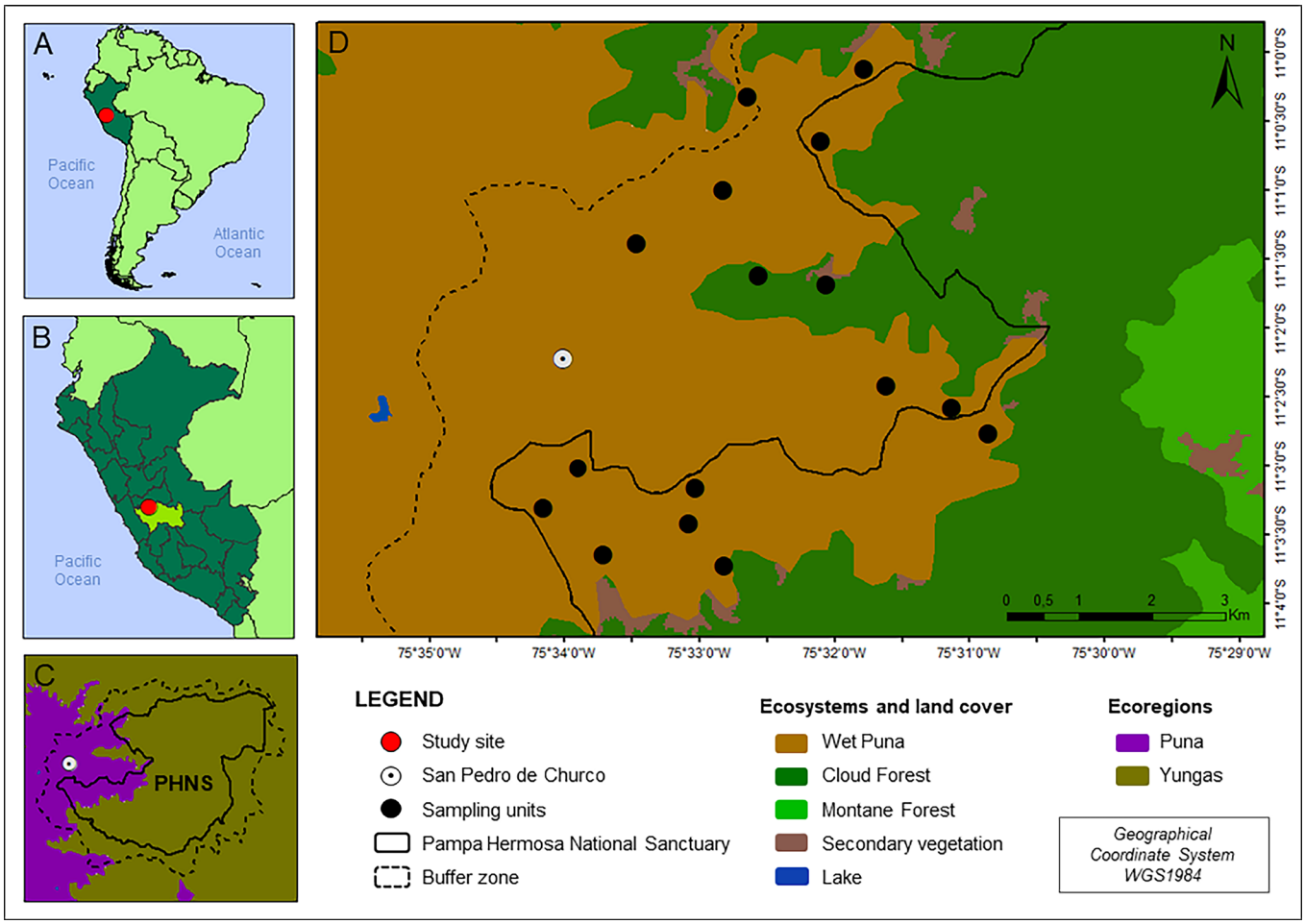


**Figure 1.** a) Location of Peru in South America and the study site; b) Location of department of Junín (light green) in Peru and the study site; c) Ecoregions covering the Pampa Hermosa National Sanctuary (PHNS) and its buffer zone and location of the S.P. Churco village; d) Ecosystems and land cover of the high-Andean region of the PHNS and its buffer zone and location of the 16 sampling units in the study area.

## 2. *Data collection*

We distributed 16 sampling points in the study site, eight inside the PHNS and eight in its buffer zone (Figure 1). We used two complementary sampling methods, camera traps and active search through transects, at a sampling unit scale of 1 km². Each sampling point was centered on a camera trap (Bushnell Trophy Cam HD 2018 ©), respecting a minimum distance of 1 km between them, with a maximum deviation of 20% being accepted, due to inaccessibility and difficulty of installation in some areas. We installed the camera traps in places commonly used by mammals through the recognition of signs and animal tracks and no bait was used to avoid the artificial attraction of animals (Srbek-Araújo & Chiarello 2013). We configured the equipment to capture three consecutive photos every 10 seconds, whenever the motion sensor was triggered. We carried out the maintenance of the camera traps every six months to change the batteries and collect the stored data. The sampling time was one year and six months (May/2019 – November/2020), a sampling effort of 4,402 traps/day.

For the methodology of active search for transects, we covered 1 km trails (of people and animals) in each of the 16 sample units, in search of mammal tracks (e.g., feces, tracks, food consumed, marks on trees) and direct visualization. The tracks found along each transect were registered and georeferenced. We carried out three visits to each sampling unit (1st: May/2019; 2nd: October/2019; 3rd: November/2020), totaling approximately 48 km of transects covered within the sample units.

## 3. *Data analysis*

For the independence of the records obtained by camera traps, we considered an interval of 1 h between the photographic records of all mammals with more than 1 kg (Srbek-Araújo & Chiarello 2005). In order to measure the sampling sufficiency of the survey, we constructed species rarefaction curves using the Estimate S 9.1.0 program (Colwell 2013) with the Chao 2 estimator. For this purpose, we used the independent records obtained through camera traps and transects, using one week as the sampling effort unit (n=76). We also calculated the relative frequency (RF) by camera traps for each taxon using the formula given in percentage: (nº records of the species/nº total records) x 100.

The scientific nomenclature used followed Pacheco et al. (2009, 2020) and Nascimento et al. (2021). For species' identifications we followed Eisenberg & Redford (1989), Pereira & Aprile (2012), and Duarte & González (2010). We also consulted specialists in cases of uncertainty in the identifications. For the identification of tracks, we used the guides of Torres (2011) and Becker & Dalponte (2013). The threat status of native species at the national level followed the Red List of Threatened Species of Peru (SERFOR 2018), and at the global level followed the International Union for Conservation of Nature's Red List of Threatened Species (IUCN 2021).

## Results

We recorded 11 native and three domestic species of medium and large mammals distributed in five orders and nine families (Table 1 and Figures 2, 3). We obtained 525 independent records through camera traps of 10 native species and three domestic mammal species in the study area. By the transect method, we obtained 70 records from four species of native mammals and three domestic species, with *Puma concolor* being the only species recorded by feces alone.

The richness of native mammals sampled (S obs.= 11) reached 91.7% of the estimated richness (S est.= 11.99 ± 1.85), showing a stabilization of the rarefaction curve from the 40th week onwards (Figure 4). The order Carnivora was the most representative, accounting for 72.7% of the native species recorded, followed by Artiodactyla and Rodentia. The native species with the highest total RF was *Odocoileus virginianus* (25.5%), followed by *Conepatus chinga* (7.8%) and *Lycalopex culpaeus* (7.0%). In addition, 90.9% of native mammals were registered in the PHNS buffer zone, surpassing the proportion found within the sanctuary boundaries, which was 63.6% (Table 1).

The proportion of endemic species of Tropical Andes recorded in the area was 27.2% (*Tremarctos ornatus*, *Pudu mephistopheles* and *Cuniculus taczanowskii*). Only two species of mammals surveyed are categorized as Vulnerable, *T. ornatus* and *P. mephistopheles*; nonetheless, only the former species is also listed as Vulnerable globally. On the other hand, *P. mephistopheles* together with *Leopardus garleppi* present deficient data for a categorization of their conservation status globally. In addition, two species (*P. concolor* and *C. taczanowskii*) are listed as Near Threatened within Peruvian territory. Finally, 63.6% of recorded native mammals have a status of Least Concern as pertains their conservation at a global level, 72.7% of them show a trend towards population reduction according to the IUCN (2021).

The domestic species *Bos taurus* had the highest number of photographic records among all the surveyed mammals and, consequently, the highest RF (31.04%), in addition to being found both inside the PHNS and in its buffer zone. In total, native species obtained 45.24% of photographic records against 54.75% of records of domestic species (Table 1).

**Table 1.** Medium and large mammals recorded in the high-Andean region of the Pampa Hermosa National Sanctuary and its buffer zone, department of Junín, Peru and Tropical Andes endemic species, sampling methods, number of records, relative frequency, recording site and national (SERFOR, 2018) and global (IUCN, 2021) conservation status of recorded species. Legend: *Domestic species. Sampling methods: camera trap (Ct); feces (Fe); carcass (Ca); food consumed (Fc); tracks (Tr); visualization (Vi). N(Ct) = number of independent records through camera traps. N(Tr) = number of records through tracks and direct views. RF(Ct) = relative frequency by camera traps. Species record location: Pampa Hermosa National Sanctuary (NS), buffer zone (BZ). Conservation status: Least Concern (LC); Near threatened (NT); Vulnerable (VU), Data Deficient (DD). Population trend (Pt) at global level (IUCN, 2021): stable (s); reducing (r).

| Taxon | Common name | Endemic | Methods | N(Ct) | N(Tr) | RF(Ct) | NS/BZ | Status conservation | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Peru | IUCN (Pt) |
| ARTIODACTYLA | | | | | | | | | |
| **Cervidae** | | | | | | | | | |
| *Odocoileus virginianus* (Zimmermann, 1780) | White-tailed Deer | - | Ct, Fe, Tr, Vi | 134 | 5 | 25.52 | NS/BZ | LC | LC (s) |
| *Pudu mephistopheles* (de Winton, 1896) | Northern Pudu | En | Ct | 3 | 0 | 0.57 | NS/BZ | VU | DD (r) |
| **Bovidae** | | | | | | | | | |
| *Bos taurus* (Linnaeus, 1758)* | Cattle | - | Ct, Fe, Tr, Vi | 163 | 33 | 31.04 | NS/BZ | - | - |
| CARNIVORA | | | | | | | | | |
| **Canidae** | | | | | | | | | |
| *Lycalopex culpaeus* (Molina, 1782) | Andean Fox | - | Ct | 37 | 0 | 7.04 | NS/BZ | LC | LC (s) |
| *Canis lupus familiaris* (Linnaeus, 1758)* | Domestic dog | - | Ct, Tr | 28 | 2 | 5.33 | NS/BZ | - | - |
| **Felidae** | | | | | | | | | |
| *Leopardus garleppi* (Matschie, 1912) | Garlepp's Pampas Cat | - | Ct | 1 | 0 | 0.19 | NS | DD | DD (r) |
| *Leopardus pardalis* (Linnaeus, 1758) | Ocelot | - | Ct | 3 | 0 | 0.57 | NS/BZ | LC | LC (r) |
| *Puma concolor* (Linnaeus, 1771) | Puma | - | Fe | - | 1 | - | BZ | NT | LC (r) |
| **Mephitidae** | | | | | | | | | |
| *Conepatus chinga* (Molina, 1782) | Molina's Hog-nosed Skunk | - | Ct | 41 | 0 | 7.8 | NS/BZ | LC | LC (r) |
| **Mustelidae** | | | | | | | | | |
| *Eira barbara* (Linnaeus, 1758) | Tayra | - | Ct | 3 | 0 | 0.57 | BZ | LC | LC (r) |
| *Mustela frenata* (Lichtenstein, 1831) | Long-tailed Weasel | - | Ct, Ca | 4 | 1 | 0.76 | BZ | LC | LC (s) |
| **Ursidae** | | | | | | | | | |
| *Tremarctos ornatus* (F. G. Cuvier, 1825) | Andean Bear | En | Ct, Fe, Fc, Tr | 10 | 19 | 1.9 | NS/BZ | VU | VU (r) |
| PERISSODACTYLA | | | | | | | | | |
| **Equidae** | | | | | | | | | |
| *Equus caballus* (Linnaeus, 1758)* | Horse | - | Ct, Fe, Vi | 97 | 9 | 18.47 | NS/BZ | - | - |
| RODENTIA | | | | | | | | | |
| **Cuniculidae** | | | | | | | | | |
| *Cuniculus taczanowskii* (Stolzmann, 1865) | Mountain Paca | En | Ct | 2 | 0 | 0.38 | BZ | NT | NT (r) |

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**Figure 2.** Medium and large native mammals recorded by camera traps in the high-Andean region of the Pampa Hermosa National Sanctuary and its buffer zone, departament of Junín, Peru: a) *Lycalopex culpaeus*; b) *Leopardus garleppi*; c) *Leopardus pardalis*; d) *Tremarctos ornatus*; e) *Conepatus chinga*; f) *Pudu mephistopheles*; g) *Odocoileus virginianus*; h) *Cuniculus taczanowskii*.

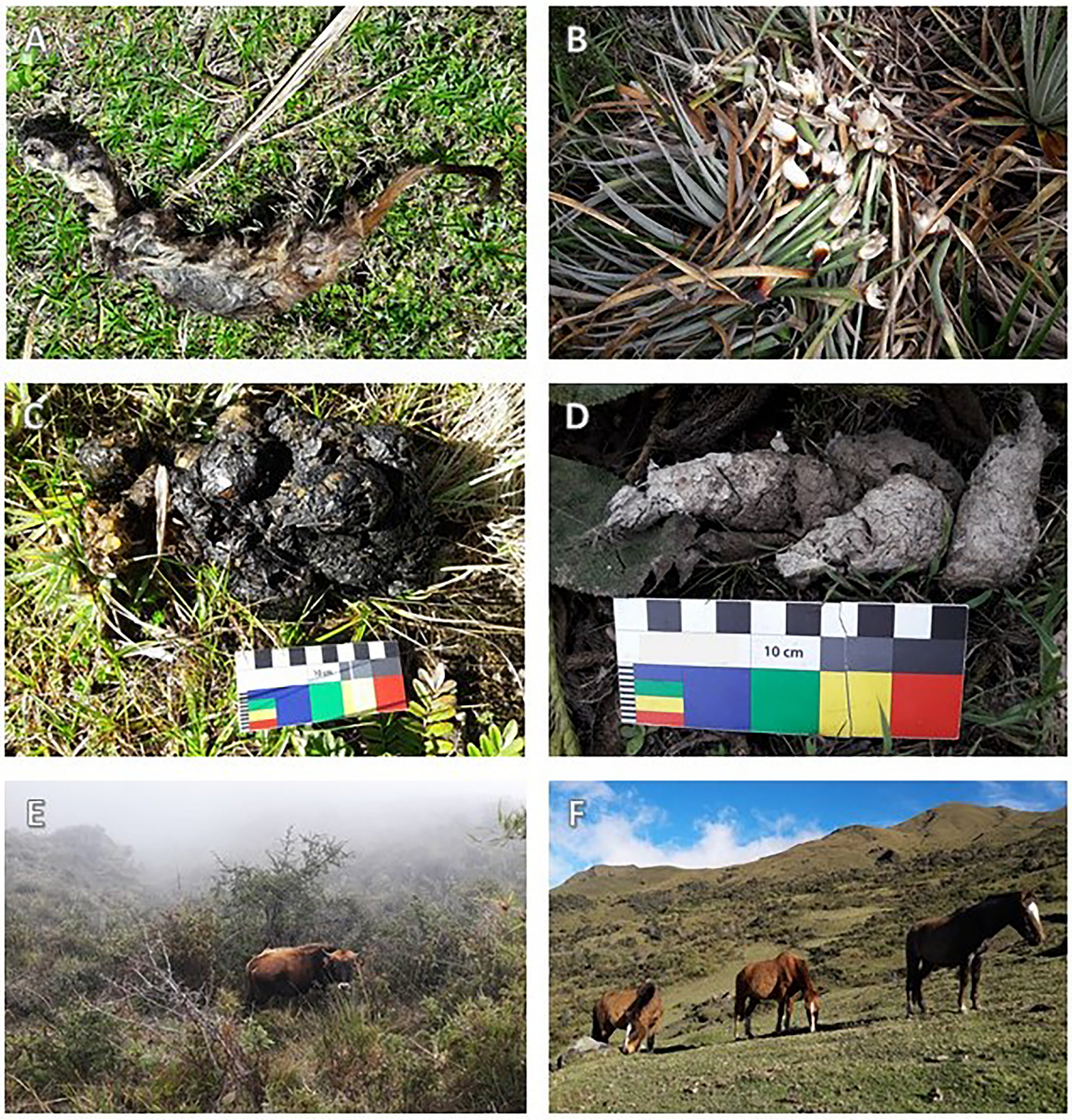


**Figure 3.** Medium and large sized mammals recorded through tracks and direct views in the high-Andean region of the Pampa Hermosa National Sanctuary and its buffer zone, department of Junín, Peru: a) *Mustela frenata* carcass; b) bromeliad of the genus *Puya* eaten by *Tremarctos ornatus*; c) *T. ornatus* feces; d) *Puma concolor* feces; e) Creole *Bos taurus* grazing native vegetation; f) *Equus caballus* grazing in the high-Andean grasslands.

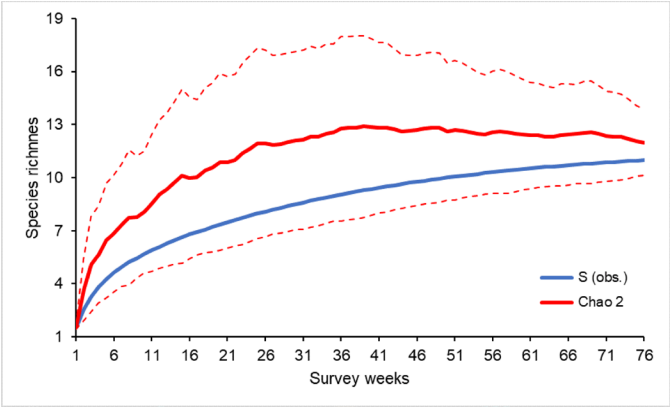


**Figure 4.** Rarefaction curve of medium and large mammals recorded in the high-Andean region of the Pampa Hermosa National Sanctuary and its buffer zone, department of Junín, Peru. Legend: Obs.: total observed richness; S est.: richness estimated by *Chao 2* (95% confidence interval – red dashed lines).

## Discussion

The present study is the first and only systematic survey that sought to inventory the medium and large mammals present in the PHNS and its buffer zone. The richness of mammals was higher than most surveys of medium and large mammals carried out between the Wet Puna and Cloud Forests (2,000 – 4,000 m) in Peruvian Eastern Andes, where the reported richness ranged from 4 to 13 species (Shanee & Shanee 2018, López 2020) (Table 2). Taking into account the altitude range of the surveys, only studies carried out in regions with a difference greater than or equal to 1,000 m obtained a higher number of species than in our study (Medina et al. 2012, Shanee & Shanee 2018), which was performed at an altitudinal amplitude of only 500 m (Table 2). Furthermore, in most of aforementioned surveys the study areas are located mostly in the Yungas region, which has a known greater diversity of mammals (Pacheco et al. 2009). Unlike our study area, where the Puna ecoregion is

dominant, there is a recognizably lower diversity of mammals compared to the Yungas (Pacheco et al. 2009, 2020). In addition, the present study is one of the few surveys that used only primary data in its methodology compared to other studies conducted in similar altitudinal ranges in the Peruvian Eastern Andes (Table 2).

The richness of medium and large mammals found in the high-Andean region of the PHNS and its buffer zone represents about 65% of the native mammal species of this group with known distribution for the study area (17 spp.) (Bernal 2016, Cassola 2016, Pacheco et al. 2009, 2020). Thus, six potential species were not recorded for the area: taruca (*Hippocamelus antisensis*), llama (*Lama glama*), Andean cat (*Leopardus jacobita*), southern mountain viscacha (*Lagidium viscacia*), hairy long-nosed armadillo (*Dasypus pilosus*), and Andean opossum (*Didelphis pernigra*). The first four species are typically found in higher rocky areas of the Andes (FAO 2005, Barrio 2010, Cossíos et al. 2012a, Bernal 2016), making it difficult to record these mammals in transition zones between Puna and Yungas (J. Barrio 2021, personal communication), especially taruca, llama and southern mountain viscacha that only occur in the Puna (Pacheco et al. 2009). The hairy long-nosed armadillo and the Andean opossum are found mainly in the Yungas (Pacheco et al. 2020), so possibly the presence of only 18% of our camera traps in the Cloud Forests of the Yungas may have rendering the recording of these two species in the area difficult.

Regarding the species richness of the two ecoregions in which the study area is located, we recorded 41.1% of the community of medium and large mammals known to occur in the Peruvian Puna ecoregion (17 spp.) (Pacheco et al. 2009, 2020). While, in relation to the Cloud Forests (>2,500 m) of the Peruvian Yungas, we found 40.7% of medium and large mammals known for this ecosystem (27 spp.) (Pacheco et al. 2009, 2020). Based on literature, *P. mephistopheles*, *L. pardalis* and *E. barbara* were only known to occur in the Yungas and other forest ecosystems in Peru (Sanborn 1953, Hurtado et al. 2016, Shanee & Shanee 2018, Pacheco et al. 2020). Nonetheless, we recorded theses three species in areas of Puna (Table 3). These are the first well-documented and georeferenced records within the Peruvian territory that confirm the presence of these three species in this Andean ecoregion. These records demonstrate the ecological plasticity of these typically forest mammals in the use of different types of environments for foraging and obtaining resources (Lyra-Jorge et al. 2008a, Escamilo et al. 2010, Lima et al. 2020, Pasa et al. 2021).

In addition, we recorded the species *P. mephistopheles*, *L. pardalis* and *E. barbara* at the highest altitudes known to the literature in Peruvian territory (Pacheco et al. 2020) (Table 3). For *P. mephistopheles* the increment was 56 m (3,506 m) in relation to the previous record of highest altitude of the species in Peru (3,450 m) (Shanee & Shanee 2018).

**Table 2.** Comparison of species richness of medium and large mammals found in the present study and in other surveys carried out in the Puna and Cloud Forest ecotones of the Peruvian Eastern Andes, in addition to the altitudinal range (in meters above sea level), altitude range amplitude (in meters) and sampling methods used in each study: camera trap (Ct); tracks and casual observations (Tr); interview (In); bibliographic review (Br).

| Article | Location | Altitudinal range (amplitude) | Methods | Richness |
|---|---|---|---|---|
| Present study | Pampa Hermosa National Sanctuary | 3,200-3,700 (500) | Ct, Tr | 11 |
| Pacheco et al. (2007) | Apurímac River Basin | 2,751-3,500 (749) | Tr, In | 10 |
| Ramirez et al. (2007) | Tupala/Acjanaco | 3,450-4,000 (550) | Tr | 7 |
| Jiménez et al. (2010) | Pagaibamba/ San Lorenzo Forests | 2,500-3,700 (1,200) | Ct | 8 |
| Medina et al. (2012) | Kcosñipata Valley | 2,550-3,600 (1,050) | Tr, In | 12 |
| Shanee & Shanee (2018) | Valley of Marañón and Huallaga Rivers | 2,000-3,000 (1,000) | Tr, In | 13 |
| Pacheco & Noblecilla (2019) | Carpish Mountain Forest | 2,700-3,000 (1,300) | Tr, In | 6 |
| Palomino & Ataucusi (2019) | Huáscaran National Reserve | 2,300-4,000 (1,700) | Br | 11 |
| López (2020) | Yanachaga-Chemillén National Park | 1,900-3,200 (1,300) | Ct | 4 |

**Table 3.** Comparison between altitudinal ranges (in meters above sea level) and high-Andean ecoregions (Puna and Yungas) of occurrence of medium and large mammal species recorded in this study in relation to known records for the Peruvian territory according to Pacheco et al. (2020). Legend: [a]According to Medina et al. (2012). [b]According to Pacheco et al. (2009). [P]Highest altitude record for the species within its range of occurrence in Peru. [G]Highest altitude record for the species for its distribution range. *These species can also occur in other Peruvian ecoregions.

| Species | Altitudinal range in Peru | Altitudinal range of records | Puna/ Yungas* | Record ecoregions |
|---|---|---|---|---|
| *Odocoileus virginianus* | 3-4,400 | 3,326-3,699 | P/Y | P/Y |
| *Pudu mephistopheles* | 2,000-3,450 | 3,379-3,506[P] | Y | P |
| *Lycalopex culpaeus* | 3-4,800 | 3,326-3,699 | P/Y | P/Y |
| *Leopardus garleppi* | 0-4,982 | 3,655 | P/Y | P |
| *Leopardus pardalis* | 150-3,379 | 3,210-3,623[G] | Y | P/Y |
| *Puma concolor* | 3-5,800 | 3,523 | P/Y | P |
| *Conepatus chinga* | 0-4,530 | 3,326-3,649 | P/Y | P/Y |
| *Eira barbara* | 150-3,379 | 3,326-3,439[G] | Y | P/Y |
| *Mustela frenata* | 1,514-4,000 | 3,326-3,573 | P/Y | P/Y |
| *Tremarctos ornatus* | 210-4,750 | 3,210-3,655 | P/Y | P/Y |
| *Cuniculus taczanowskii* | 1,920-3,530[a] | 3,326-3,469 | P/Y[b] | P/Y |

However, throughout its distribution, this small deer has already been found at 4,500 m in the Ecuadorian Páramos (Escamilo et al. 2010). As for *L. pardalis*, the altitudinal increment was 244 m (3,623 m) whereas for *E. barbara* it was 60 m (3,439 m) compared to previous records of 3,379 m recorded by Jiménez et al. (2010) for both species in northern Peru (Table 3). These species are rarely reported for such high altitudes, and the altitudinal distribution of *E. barbara* hardly exceeds 1,200 m (Cuarón et al. 2016), while *L. pardalis* is uncommon to be found above 3,000 m (Paviolo et al. 2016). Thus, these records of *L. pardalis* and *E. barbara* are also the ones with the highest altitude for the entire area of occurrence of these two Neotropical carnivores.

The order Carnivora was the most representative in the study area, having 72.7% of the species belonging to this taxon, although most of them have a low relative frequency. Our results are similar to other studies with medium and large mammals conducted in transitional Puna-forest regions in the Peruvian Andes (Pacheco et al. 2007, Jiménez et al. 2010, Medina et al. 2012, Shanee & Shanee 2018). Despite occurring at low densities, species of this order have large home ranges and high mobility (Robinson & Redford 1986, Hodge & Arbogast 2016), increasing the probability of these mammals being detected at least once, certainly depending on the sampling effort. Furthermore, most of the registered carnivores have generalist habits, having the ability to explore resources in different environments (Lyra-Jorge et al. 2008b, Cossíos et al. 2012b), moving from more forested landscapes such as the Cloud Forests, to open areas like the Puna. The presence of large top-chain carnivores, such as *Puma concolor* and *Tremarctos ornatus*, also demonstrates that the high-Andean region of the PHNS and its buffer zone has healthy populations of prey and good environmental integrity (Cardillo et al. 2004).

Among the recorded native species, *Odocoileus virginianus* had the highest relative frequency (25.5%), and this rate is even higher when compared only among records of native mammals (56%). Such a high relative frequency of this deer species for the Eastern Andes has never been reported in the literature. The highest relative frequency recorded for *O. virginianus* reported for the Eastern Andes was 15.2% found by Jiménez et al. (2010) in a survey carried out in the Páramos and Cloud Forests of northern Peru. For other areas of Latin America with occurrence of the species, such as Protected Areas of Mexico, Honduras and Ecuador, this frequency rate varies from 1 to 9% only (Monroy-Vilchis et al. 2011, Gonthier & Castañeda 2013, Lizcano et al. 2016). Despite occurring in several ecosystems of the Neotropical region, *O. virginianus* presents greater abundances in dry tropical forests and regions of grassland-forest ecotone, such as our study area (Delfin 2002, Gallina et al. 2010). Furthermore, in the high-Andean zones there is a partitioning of habitat use between *O. virginianus* and *Hippocamelus antisensis*, with *O. virginianus* tending to avoid such high altitudes (> 3,700 m) and rocky environments (Barrios 2006), but it also does not have a great preference for tropical rainforests, such as the Yungas (Palomino & Ataucusi 2019). For these reasons, the high relative abundance of this deer is due to the altitudinal range and the puna-forest ecotone that the study area is located in, generating very favorable environmental conditions for the establishment of the species. Therefore, the high presence of *O. virginianus* in the area makes the high-Andean zone of PHNS a key location in Peru for potential ecological studies of the species, which still lacks information on its population and conservation status in the Peruvian territory (Gallina et al. 2010).

Among all recorded mammals, *Bos taurus* was the most frequent. The high presence of this domestic species in the area is due to the extensive livestock by the high-Andean rural communities (Paisley 2001, Goldstein 2002). The absence of more productive livestock management makes the rustic cattle move freely over extensive areas, enabling interaction with native species, generally in a negative way (Goldstein et al. 2006). A study by Barrio (2006) in the Peruvian Andes showed that the presence of cattle has a negative effect on the habitat use of native deer *O. virginianus* and *H. antisensis*, displacing these species to other areas. On the other hand, this extensive livestock makes the cattle very vulnerable to attacks from native predators such as pumas, foxes and Andean bears, generating retaliation by local communities and, consequently, persecution of these carnivores (Goldstein et al. 2006, Rojas-Vera Pinto et al. 2019). In addition, unmanaged cattle grazing in these high-Andean regions can impact negatively the soil, the water retention of the high-Andean mash, the biodiversity of plants, aquatic macro invertebrates and even the abundance of specialist birds in the upper Andean grasslands (Astudillo et al. 2018, Avellaneda-Torres et al. 2018, Machaca et al. 2018, Meza-Salazar et al. 2020).

The proportion of endemic species of Tropical Andes as *Cuniculus taczanowskii*, *T. ornatus*, and *P. mephistopheles* was relatively low for the area. This might be explained by the fact that the study was mostly carried out in the Puna ecorregion, which has an endemism rate of only 15.4% in Peruvian territory (Pacheco et al. 2009). In turn, the Yungas and the Low Jungle are the ecoregions with the largest number of endemic mammal species in the Tropical Andes (Myers et al. 2000, Pacheco et al. 2009, 2020).

According to the IUCN, about 73% of the species registered in the study show a trend towards population reduction, indicating the relevance of the area for mammal conservation. However, only two species (*T. ornatus* and *P. mephistopheles*) are listed as threatened in Peru (Velez-Liendo & García-Rangel 2018, SERFOR 2018), and globally, *P. mephistopheles* still lacks data to define its current conservation status (Barrio & Tirira 2019). Considered as smallest deer in the world, *P. mephistopheles* is still a poorly known species, especially the populations of central Peru, which are isolated from populations north of the Andes (Ecuador and Colombia), where there is more information about the species (Escamilo et al. 2010). Due to its low density, the record of three individuals of *P. mephistopheles* at the study site highlights the importance of the conservation of this area to maintain this species in the region.

Although the area belonging to the PHNS has a good conservation status of its Andean-Amazonian ecosystems, its surrounding areas are being impacted by human activities at different levels (SERNANP 2012). Extensive livestock and firewood extraction are the main threats to the ecosystems of the high-Andean region of the sanctuary's buffer zone, where the S.P. Churco village is located. Despite having a high environmental vulnerability, our results showed that more than 90% of the species recorded were found outside the sanctuary boundaries, showing that this high-altitude buffer zone has an important value for the high-Andean mammals. However, these anthropogenic disturbances added to climate change, could strongly impact the diversity, abundance, and distribution of these mammals in the long term, mainly if natural resources are not rationally used.

As the first systematic survey of medium and large mammals for the PHNS region, we demonstrate that the area has a good representation of this biological community in the high zone of the Peruvian Eastern Andes.

In addition, this study is one of the few surveys concentrated on the Wet Puna that only uses primary data and one of the first for the entire Peruvian department of Junín. Biological knowledge gaps in the high-Andean ecosystems are still huge in most Peru. The results we presented here offer new and important information on the local diversity of mammals, as well as updates on the altitudinal distribution of some species. However, further studies are needed on the biodiversity of the high-Andean zone of the PHNS and its surroundings, mainly because the high-Andean ecosystems are the most vulnerable and threatened to climate change throughout the Tropical Andes.

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## Conflicts of Interest

The authors declare that there are no conflicts of interests related to the publication of this manuscript.

## Ethics

The authors declare compliance with all guidelines established by ethics committees' universities and government agencies involved. They also state that the manuscript has not been previously published.

## Data Availability

The authors declare that the data present in this manuscript may have open access. The data resulting from this research has been archived in the public data repository Biota Neotropica Dataverse, that provides free access and guaranteed preservation. Access URL: https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/scielodata.3KOVKP.

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