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Chapter

Conservation Status of Macro Mammals in the Llanganates-Sangay Ecological Corridor and Anzu River Subbasin

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Abstract

With rapid ecological assessments, we diagnose the conservation status of large mammals in the localities Rio Encanto, San Jacinto Las Palmas, Sacha Llanganates, Cabeceras del Anzu, Boayaku, and Flor de Bosque, located within the Llanganates Sangay Ecological Corridor (CELS) and the upper subbasin of the Anzu River, in the eastern foothills of the tropical Andes, sub-Andean and tropical ecosystems in one of the most biologically diverse regions of Ecuador. Camera traps, 5 km linear transect walks, and interviews with local inhabitants recorded 35 species of macro mammals, in 8 Orders and 21 Families, including the Andean bear (*Tremarctos ornatus*), Andean tapir (*Tapirus pinchaque*), Amazonian tapir (*Tapirus terrestris*), puma (*Puma concolor*), and chorongó monkey (*Lagothrix lagotricha*), mammals considered as flagship species, highly endangered. The continuity of natural habitat along the subbasins of the Encanto, Topo, Zuñag, Tigre, and Anzu rivers, as well as the mountain ranges toward the highlands, provide favorable conditions for the flow of individuals, from adjacent areas of the Llanganates and Sangay National Parks to partially protected forest areas, such as the private reserves of Fundación Ecominga, Sumak Kawsay in Situ, community reserves of Boayaku and Flor de Bosque. The protection of the area is a priority.

Keywords: rapid ecological assessment, Ecuadorian flagship species, tropical Andes, threatened species, sub-Andean ecosystems

1. Introduction

Western Amazonia is one of the most biodiverse areas on the planet and the most biologically rich part of the entire Amazon basin [1]. The Llanganates-Sangay Ecological Corridor (CELS) is located between the provinces of Tungurahua, Pastaza, and Morona Santiago, in the central Andean and eastern foothills of the Ecuadorian Andes; it covers about 679 km²; it is more than 40 km long and between 6 and 20 km wide, between the Llanganates and Sangay National Parks. While the upper subbasin of the Anzu River connects part of the declared corridor and the buffer zone of the

Llanganates National Park, with more tropical areas in the upper Amazon of Pastaza and Napo provinces.

The CELS is one of the areas considered a priority for conservation efforts, due to its strategic location, variety of habitats and ecosystems, and the functions they play in maintaining the planetary climate balance. Likewise, the Anzu River subbasin is located in the conservation hotspot, so the diagnosis of its conservation status is important due to its location in the westernmost portion of the eastern foothills of the central Ecuadorian Andes.

The importance of ecosystems such as the cloud forest and sub-Andean Forest for the regulation of the water cycle is well known, as well as for the alpha diversity and endemism of fauna and flora that these ecosystems contain. On the other hand, both areas are connected with protective forests such as the Abitahua Protected Forest, and are also crossed by cities, population centers, and agricultural activities that exert pressure on this biodiverse area [2].

The corridor was declared a gift of the earth [3] due to the richness of its ecosystems, flora, and fauna. However, the use of this space has not been well analyzed, especially in the area of influence of the Abitahua Protected Forest and the upper subbasin of the Anzu River. There is insufficient information on the fulfillment of its function as a biological corridor. The areas through which the genetic flow of large mammals exists and which may be under pressure from agricultural activities, deforestation, population centers, road traffic, natural barriers, and social-cultural aspects of the population, which influence the ecosystems and species, are unknown.

In this context, the present study sought to diagnose the conservation status in areas of the CELS and the upper subbasin of the Anzu River, through field sampling with camera traps in selected sites in the region between the towns of Rio Negro, in Tungurahua province, and Boayaku, in Pastaza province.

The main results corresponding to a baseline for biological monitoring during 6 months of work focused on the Masto fauna of the upper basin of the Anzu River and other localities belonging to the CELS are presented. The results obtained represent an approach to the full knowledge of the conservation status of this important ecological zone, being nevertheless an important contribution to the continuity of research and conservation efforts in the short and medium term, with a view to safeguarding the great biodiversity of the environment and ecosystems that make up this biodiverse region.

2. Materials and methods

The study area corresponds to the life zones of very humid tropical forest, humid tropical forest, and Andean brow [4], located between 750 and 2100 m above sea level. According to [5], it corresponds to the Pie montane evergreen forest, montane cloud forest, and montane evergreen forest vegetation formation of the Eastern Andes, where annual rainfall of 3000–4000 mm, a temperature ranging between 12 and 24°C and relative humidity of 80–90% is recorded.

Study area is conceived as a macro-thermal rainforest of the eastern region or Amazonian hylea [6], where average temperatures remain within 24°C and rainfall exceeds 6000 mm [6], being within one of the rainiest areas of Ecuador, due to the direct influence of high rainfall areas such as the Abitahua Protected Forest and the CELS.

It is a transition zone between the Amazonian lowlands and the tropical Andes, forming part of the buffer zone of Llanganates National Park and Sangay National Park in the CELS. This geographical feature has given rise to a range of habitat types and microclimates within an altitudinal gradient that ranges from dense forest with sub-canopies below 15 m in the lowlands to open forest with emergent canopies of 20–30 m from 1000 m altitude.

As this is a foothill area of the eastern Andean range, there are buttresses with slopes of 60–70° and abundant bodies of water: springs, streams, and rivers that descend through the foothills of the mountain range. The main subbasins of the area correspond to the Pastaza River, which receives the waters of the Encanto, Topo, Zuñag, Tigre, and Alpayacu rivers, while the Anzu River flows north and empties into the Napo River in the province of the same name.

2.1 Locations and sampling sites

Fieldwork focused on six localities in three provinces, Morona Santiago, Pastaza, and Tungurahua, with emphasis on the subbasin of the Anzu River (**Table 1**), selected based on criteria of connectivity with protected areas, forest quality, as well as previous records or interviews on the presence of endangered species [7].

2.1.1 Rio Encanto

Located in the north-eastern buffer zone of Sangay National Park, Río Encanto protects an important area of evergreen piedmont forest between the provinces of Tungurahua and Morona Santiago. The area is a mosaic of several farm owners, the vast majority of whom have abandoned intensive agricultural activities for more than 40 years, which has kept the forest well preserved. There is a constant connectivity vegetation through the upper lands to Pastaza River's mouth (**Figure 1**).

Location	Province	Municipality	Easting (m)	Northing (m)	Altitude (m) over sea level
Río Encanto (Encanto River)	Tungurahua–Morona Santiago	Baños–Palora	810,024*	9,838,230	1400–1800
San Jacinto las Palmas	Tungurahua	Baños	813,438*	9,850,095	1800–2100
Sacha Llanganates	Tungurahua–Pastaza	Baños–Mera	816,649*	9,847,837	1500–3000
Cabeceras del Anzu (Headwaters of the Anzu River)	Pastaza	Mera	828,840*	9,844,063	1100–1450
Boayaku	Pastaza	Mera	168,411**	9,853,573	819
Flor de Bosque (Forest Flower)	Pastaza	Santa Clara	172,907**	9,857,929	719

*Universal Transverse Mercator, World Geodetic System, zone 17 South.
 **Universal Transverse Mercator, World Geodetic System, zone 18 South.

Table 1. Location of study sites. Geographical coordinates collected by the authors in the field work.



Figure 1.
Location of Río Encanto.



Figure 2.
Location of San Jacinto las Palmas.

2.1.2 San Jacinto las Palmas

This place is located toward the high zone of colony Azuay, the southern buffer zone of the Llanganates National Park. It has important remnants of montane cloud forest and includes a mountain range in an easterly direction up to the origins of the Tigre and San Jacinto rivers, forming part of the lands of the San Jacinto las Palmas Association, on its limits with the Zuñag River Basin Ecological Association (**Figure 2**).

2.1.3 Sacha Llanganates

This locality crosses the southern buffer zone of the Llanganates National Park, up to the high zone of the Abitagua mountain range, ascending through the Zuñag river basin to the origins of the Anzu River between the provinces of Tungurahua and Pastaza. It includes part of the conservation area of the Zuñag River Basin Ecological Association and part of the Zuñag River Reserve of the Ecominga Foundation. It conserves a great variety of ecosystems from evergreen foothill montane forest to high montane evergreen forest (**Figure 3**).

2.1.4 Cabeceras del Anzu

This locality constitutes the upper zone of the Anzu River, entering through Mera municipality, in the way to 24th May colony, within the Anzu River



Figure 3.
Location of Sacha Llanganates.

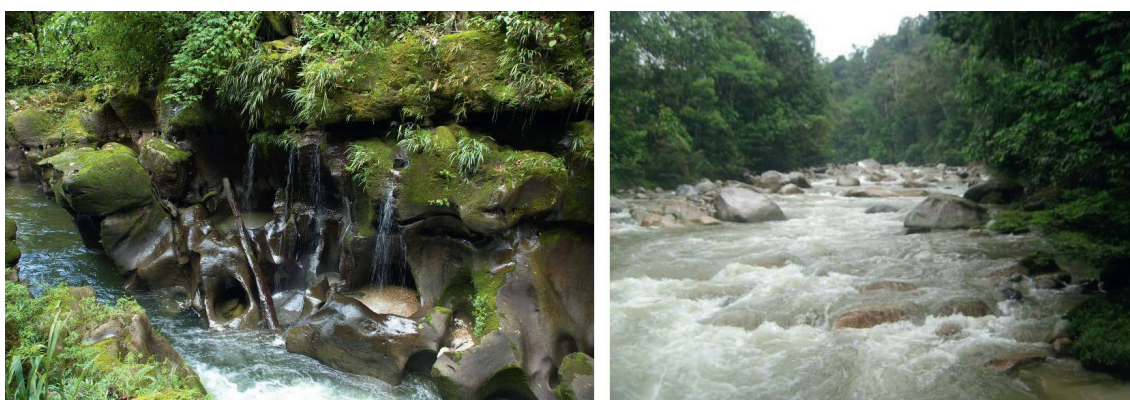


Figure 4.
Location of Cabeceras del Anzu.

Ecological Reserve of the Ecominga Foundation and the Sumak Kawsay in Situ conservation area. The place conserves important remnants of low montane evergreen forest and montane foothills, surrounded by heavily disturbed farms (**Figure 4**).

2.1.5 Boayaku and Flor de Bosque

Those localities are located in the lower portion of Anzu River; correspond to indigenous peasant colonies and communities, made up of one populated center of peasant settlers (Boayaku) and another by the indigenous community (Flor de Bosque). This populated sector forms part of Pastaza municipalities, on the right bank of the Anzu River, and form a part of Mera municipality on the left bank of the same river. Other hydrographic tributaries of the Anzu River, such as the Chontayaku and Challuayaku Rivers, are also found in the area. It is worth noting that a part of the territory of Boayaku (**Figure 5**) is a part of the Abitahua Protected Forest, while almost all of the areas is part of the buffer zone of the Llanganates National Park (**Figure 6**).



Figure 5.
Location of Boayaku.



Figure 6.
Location of Flor de Bosque.

2.2 Methods

2.2.1 Biological and ecological assessments of Masto fauna biodiversity

Field expeditions were carried out covering most of the territory of influence of the populated settlements between the communities of Río Negro (Tungurahua) and

Boayaku (Pastaza), in the area that forms part of CELS and the upper subbasin of the Anzu River. These expeditions are part of the baseline diagnosis that allows, on the one hand, to determine the conservation status of the visited sites, and, on the other hand, to identify potential sampling sites for monitoring with camera traps, taking into account variables such as proximity to population centers, connectivity of habitats and ecosystems, logistical and operational aspects. In each outing, a multidisciplinary team carried out a rapid biological and ecological assessment of the state of conservation of the environment in terms of large fauna (macro mammals).

The information was collected in structured biological and ecological characterization sheets, obtaining records of direct and indirect observations (feces, footprints in tracks, diet, etc.). Interviews were conducted with local guides and members of the communities and the study localities were geo-referenced as well as different points of interest such as areas of faunal abundance and salt licks, among others.

In total, 18 field inspections were conducted, completing 36 effective sampling days from August to March, before COVID-19 pandemic time, at 6 locations with an average of 30 km of trails, with permanent sites for direct and indirect record monitoring, thus determining the best sites for camera trap installation, track recording and field observations.

2.2.2 Macro mammal monitoring with camera traps

Photo-trapping monitoring was carried out using Bushnell Trophy Cam HD camera traps placed along field transects to obtain information on the presence/absence of large mammals such as the Andean tapir, Amazonian tapir, Andean bear, puma, and panthera, among others, considered indicator species of the quality and conservation of the environment in the study area. The cameras were placed at intervals of 20–40 days in the fields in order to identify potential areas of mammal flow and occurrence of indicator species (presence/absence), among other aspects.

2.2.3 Interviews about use and pressure on macro mammals

Semi-structured interviews were conducted with the field guides and communities members with whom we worked during the study. In this way, it was possible to complement the record of species that could not be directly observed during the fieldwork and to learn about their use, conservation status, socio-cultural pressure, and trends in land use and exploitation that generate pressures on the environment and the conservation of large mammals.

3. Results

3.1 Macro mammals' communities in the study area

Analysis of fieldwork records and interviews with local people yielded a richness of 35 species of large and medium-sized mammals for the study area (**Table 2**). The Order Carnivora is the best represented with 11 species, the family Felidae the most numerous with 5 species, followed by the family Mustelidae ($n = 3$), Procyonidae ($n = 2$), and Ursidae with only 1 species. Order Rodentia is the second more numerous

with 7 species, corresponding to Family Sciuridae ($n = 3$), followed by Dasyproctidae ($n = 2$); Erethizontidae and Cuniculidae have 1 species each. The Order Primates has 5 species: Family Atelidae ($n = 2$), Cebidae, Callitrichidae, and Aotidae ($n = 1$). Order Artiodactyla (2 Families) and Pilosa (4 Families) have 4 species each; Perissodactyl ($n = 2$); Lagomorpha and Cingulate were represented by only 1 species.

In reference to [8], for 2021, according to the threatened categories reported by the International Union for Conservation of Nature (IUCN), there are 2 species in Critically Endangered (CR), 8 species in Endangered (EN), 3 Vulnerable (VU) in the extinction risk. Also, 8 species are in Near Threatened (NT) status and 13 species in the Least Concern (LC); there are Data Deficient (DD) for 1 species (**Table 2**).

Condensing data from all sampled localities by the number of records per species, the Andean tapir (*Tapirus pinchaque*) obtained the highest number of records, followed by the tigrillo (*Leopardus tigrinus*), Amazonian cuichucho (*Nasua nasua*), guanta (*Cuniculus paca*), and armadillo (*Dasybus novemcintus*), among the most abundant.

The record of richness by study locality placed the Cabeceras del Anzu as the area with the highest species diversity, followed by Sacha Llanganates and the lower part of the Anzu River corresponding to Boayaku–Flor de Bosque, as detailed below.

3.1.1 Río Encanto

A total of 21 species were registered belonging to 6 orders and 16 families. The most abundant orders being Carnivora ($n = 7$) and Rodentia ($n = 4$), followed by Artyodactyla ($n = 4$), Primates ($n = 3$), Pilosa ($n = 2$), and Perissodactyla ($n = 1$).

3.1.2 San Jacinto las Palmas

In San Jacinto were recorded 15 species of mammals, represented by 6 orders and 10 families. The most abundant order being Carnivora ($n = 8$), followed by Rodentia ($n = 2$), Primates ($n = 2$), and Artyodactyla ($n = 1$), Pilosa ($n = 1$), and Perissodactyla ($n = 1$).

3.1.3 Sacha Llanganates

A total of 19 mammal species were recorded, grouped into 6 orders and 14 families. The order with the highest diversity being Carnivora ($n = 7$), followed by Primates ($n = 5$), Rodentia ($n = 3$), Pilosa ($n = 2$), and Artyodactyla ($n = 1$), and Perissodactyla ($n = 1$).

3.1.4 Cabeceras del Anzu

A total of 30 species of mammals were recorded in this location, belonging to 8 orders and 19 families, the most representative was Carnivora with 10 species, followed by Primates ($n = 5$), Rodentia ($n = 5$), Artyodactyla ($n = 4$), Pilosa ($n = 2$), Perissodactyla ($n = 2$), Lagomorpha ($n = 1$), and Cingulata ($n = 1$).

3.1.5 Boayaku and Flor de Bosque

At these two localities, corresponding to the lower Anzu River, 22 species of mammals were recorded, belonging to 7 orders, and 16 families. The most representative orders

Order	Family	Specy	Local name	Location	Altitude (m) over sea level	IUCN	Register type
Carnivora	Felidae	<i>Panthera onca</i>	Tigre/Pantera	ANZ	500–1500	EN	I
		<i>Puma concolor</i>	Puma o león	ENC, SJC, SLL, ANZ, BYK, FB	1800–3800	EN	S, F, I
		<i>Herpailurus yagouaroundi</i>	Jaguarundi/Pantera	ANZ, BYK, FB	1100–1300	NT	S
		<i>Leopardus pardalis</i>	Tigrillo/Ocelote	ANZ, BYK, FB	1100–1300	NT	S, F, I
		<i>Leopardus tigrinus</i>	Tigrillo chico	ENC, SJC, SLL, ANZ	1500–2800	VU	S, F, I
	Mustelidae	<i>Lontra longicaudis</i>	Nutria o perro de agua	ENC, SJC, SLL, ANZ	1100–1500	VU	S, F, I
		<i>Eira barbara</i>	Cabezamate	ENC, SJC, SLL, ANZ, BYK, FB	1100–3000	LC	S, F, I
		<i>Neogale frenata</i>	Chucuri	ENC, SJC, SLL, ANZ	1500–2000	LC	S, F, I
	Procyonidae	<i>Nasua nasua</i>	Cuchucho/Coatí	ENC, SJC, SLL, ANZ, BYK, FB	1100–1800	NT	S, F, I, O
		<i>Nasua nasua dorsalis</i>	Tejón	SJC, SLL	2000–3000	NT	S, I
Ursidae	<i>Tremarctos ornatus</i>	Oso de anteojos	ENC, SJC, ANZ, BYK	1500–3800	EN	S, F, I	

Order	Family	Specy	Local name	Location	Altitude (m) over sea level	IUCN	Register type
Rodentia	Sciuridae	<i>Hadroskiurus spadiceus</i>	Ardilla	ENC, SJC, SLL, ANZ, FB, BYK	1500–3000	LC	O
		<i>Hadroskiurus igniventris</i>	Ardilla	BYK, FB	1000	LC	O
		<i>Microsciurus flaviventer</i>	Ardilla chiquita	ANZ	1100–1200	LC	O
	Dasyproctidae	<i>Myoprocta praatti</i>	Guatin	BYK, FB	800	LC	O
		<i>Dasyprocta fuliginosa</i>	Guatusa	ENC, SJC, SLL, ANZ, BYK, FB	1100–1800	LC	S, F, I
	Erethizontidae	<i>Coendou sp</i>	Erizo	ENC, SLL, ANZ	1800	DD	I
Cuniculidae	<i>Cuniculus paca</i>	Guanta	ENC, ANZ, BYK, FB	1100–1800	NT	S, F, I	
Primate	Atelidae	<i>Alouatta seniculus</i>	Mono ahullador	SLL, ANZ	1500–2000	VU	I
		<i>Lagothrix lagothricha</i>	Chorongo	ENC, ANZ, SLL, BYK	1500–2100	EN	O, I
	Cebidae	<i>Cebus capucinus</i>	Mono cenizo	ENC, SJC, SLL, ANZ, BYK	1100–2000	CR	O, I
	Callitrichidae	<i>Leontocebus lagonotus</i>	Chichico	SLL, ANZ, BYK, FB	1100–1800	NT	O, I
	Aotidae	<i>Aoutus sp</i>	Mono nocturno	ENC, SJC, SLL, ANZ	1100–2000	EN	O, I
Artiodactyla	Tayassuidae	<i>Tayassu pecari</i>	Pecari de labio blanco	ENC, ANZ, BYK, FB	1100–1500	EN	S, F, I
		<i>Dicotyles tajacu</i>	Zajino	ENC, ANZ, BYK, FB	1100–3000	NT	I
	Cervidae	<i>Mazama americana</i>	Venado	ENC, ANZ, BYK, FB	1200	NT	S, F, I
		<i>Mazama rufina</i>	Chiva de monte	ENC, SJC, SLL, ANZ	1500–3000	EN	S, F, I, O
Pilosa	Bradypodidae	<i>Bradypus variegatus</i>	Perezoso variegado	BYK, FB	800	LC	I
	Cyclopedidae	<i>Cyclopes ida</i>	Flor de Balsa	BYK, FB	1000	LC	I
	Megalonychidae	<i>Choloepus didactylus</i>	Perico ligero/ perezoso	ENC, SJC, SLL, ANZ	1100–2000	LC	O, I
	Myrmecophagidae	<i>Tamandua tetradactyla</i>	Oso hormiguero	ENC, SLL, ANZ, BYK	1100–2000	LC	O

Order	Family	Specy	Local name	Location	Altitude (m) over sea level	IUCN	Register type
Perissodactyla	Tapiridae	<i>Tapirus pinchaque</i>	Danta o tapir	ENC, SJC, SLL, ANZ	1500–3800	CR	S, F, I
		<i>Tapirus terrestris</i>	Danta o tapir	ANZ, BYK, FB	1100–1200	EN	F, I
Lagomorpha	Leporidae	<i>Sylvilagus defilippi</i>	Conejo	ANZ	1100–3600	LC	F, I
Cingulata	Dasypodidae	<i>Dasybus novemcinctus</i>	Armadillo	ANZ, BYK, FB	1100–1300	LC	S, F, I, O

Locations: ENC, Encanto River (Río Encanto); SJC, San Jacinto las Palmas; SLL, Sacha Llanganates; ANZ, Headwaters of the Anzu River (Cabeceras del Anzu); BYK, Boayaku; FB, Forest Flower (Flor de Bosque). IUCN register: CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern; DD, Data Deficient. Register: S, smears (feces); F, footprints; I, interview; O, observed.

Table 2.
Large mammal's species reported from localities in the CELS and Anzu River subbasin.

being Carnivora with 6 species and Rodentia with 4 species. Order Primate has 3 records, Artyodactyla ($n = 3$), Pilosa ($n = 3$), Perissodactyla ($n = 1$), and Cingulata ($n = 1$).

3.2 Conservation status of macro mammals in the study area

The six study localities maintain faunal mass communities in a good state of conservation. Taking into account the main groups of herbivores and carnivores expected for the region, representative species were recorded in all sites, demonstrating a relative balance in the food chain and trophic niche of the community. However, there are specific variations in species composition and abundance for each locality, a result of the large altitudinal variation, microclimate, and range of anthropogenic pressures for each sampling site.

Localities in the lower zone are exposed to greater hunting pressure and habitat conversion due to their proximity to communities and population centers, while localities in the upper zone are home to a greater number of records belonging to threatened species due to the difficult topography, vegetation connectivity, proximity to the Llanganates and Sangay National Parks, as well as conservation initiatives developed in the area by different actors.

In terms of threatened categories formulated with IUCN criteria, according to [9], there are 10 globally threatened macro mammal's species in the red list of mammals of Ecuador for 2011 (**Table 3**), corresponding to Critically Endangered ($n = 1$), Endangered ($n = 5$) and Vulnerable ($n = 4$).

The IUCN categories applied in the Red Book of Mammals of Ecuador for 2021 [8], increase to 13 species in risk (**Table 3**): Critically Endangered ($n = 2$), Endangered ($n = 8$), and Vulnerable ($n = 3$). From 2011 to 2021, two species reduce risk, evolving from Endangered to Vulnerable, and from Vulnerable to Near Threatened. One species increases the risk from Vulnerable to Endangered and 4 species are considered Near Threatened in 2011 appears increasing the risk to Critically Endangered, Endangered, and Vulnerable.

The most threatened species for 2021 are the mountain tapir *T. pinchaque* and *Cebus capucinus*, considered Critically Endangered (CR). *T. pinchaque* is one of the species with the highest number of records in the localities of Río Encanto and San Jacinto, these being strategic sites for the conservation of species in the region. Those places are also important sites for the life area of the spectacled bear (*Tremarctos ornatus*), which is considered Endangered (EN).

In the middle and lower zone, the localities of Cabeceras del Anzu, Boayaku, and Flor de bosque present eventual records of the Amazonian tapir (*Tapirus terrestris*) considered Endangered (EN), so it is a threatened species whose long-term viability depends on the plans and programs that can be implemented to ensure the conservation of this and other species that are indicators of healthy ecosystems.

3.3 Ecological aspects of indicator species in the study area

The mammal community in the studied localities is composed of 11 species of carnivores of which 5 species are the main predators. Also, the spectacled bear *T. ornatus* is a typical species of cloud forest and Andean moorlands whose presence in the lower localities may be due to seasonal variations in its distribution, as generally in winter the animals tend to descend to warmer areas in search of food.

During the surveys carried out in the localities of San Jacinto, Rio Encanto, and Sacha Llanganates, several species of palms belonging to the genera *Aiphanes*,

Species	Threat category (2011)	Threat category (2021)
<i>Tapirus pinchaque</i>	Critically Endangered (CR)	Critically Endangered (CR)
<i>Panthera onca</i>	Endangered (EN)	Endangered (EN)
<i>Tremarctos ornatus</i>	Endangered (EN)	Endangered (EN)
<i>Lagotrix lagotricha</i>	Endangered (EN)	Endangered (EN)
<i>Tapirus terrestris</i>	Endangered (EN)	Endangered (EN)
<i>Puma concolor</i>	Vulnerable (VU)	Endangered (EN)
<i>Leopardus tigrinus</i>	Vulnerable (VU)	Vulnerable (VU)
<i>Lontra longicaudis</i>	Endangered (EN)	Vulnerable (VU)
<i>Nasua nasua dorsalis</i>	Vulnerable (VU)	Near Threatened (NT)
<i>Mazama rufina</i>	Vulnerable (VU)	Endangered (EN)
<i>Cebus capucinus</i>	Near Threatened (NT)	Critically Endangered (CR)
<i>Aoutus sp</i>	Near Threatened (NT)	Endangered (EN)
<i>Tayassu pecari</i>	Near Threatened (NT)	Endangered (EN)
<i>Alouatta seniculus</i>	Near Threatened (NT)	Vulnerable (VU)

Table 3.
 Threatened macro mammals according to the Red Book of Ecuadorian Mammals for 2011 [9], compared with 2021 [8].

Ceroxylum, *Geonoma*, and *Dictyocarium* were observed being consumed by the bear. In addition, some trees of the genus *Vizmia* were observed used exclusively by males for gurgling and possibly to mark territory.

The mountain tapir *T. pinchaque* and its Amazonian counterpart *T. terrestris*, are indicator species of habitat quality, since generally in the areas where *Tapirus* genus was recorded, the general species composition is practically in its original state and the forest is well conserved. Both species are considered gardeners of the forest, as they contribute to seed dispersal, regulation of the growth of some plants, and maintenance of soil fertility. During the sampling, it was possible to record several species of plants consumed by the Andean tapir, among which the genera *Pilea*, *Piper*, *Solanum*, and *Gunnera* stands out, as has been described in previous studies in other localities [10].

4. Discussion

4.1 Flow areas and ecological corridors: importance of the studied localities for the conservation of biodiversity in the area

Large mammals can be good indicators of habitat quality and conservation status. In the present study, sampling areas were distributed along a gradient of human disturbance, from areas close to anthropogenic activities, through secondary forest to pristine forest with little disturbance. The results obtained reflect the presence of 35 species of macro mammals in the study area, 13 of which are at different levels of extinction threat.

Four species of large mammals recorded during the sampling need living areas greater than 500 hectares per individual [9]: *T. pinchaque*, *T. terrestris*, *T. ornatus*,

and *Puma concolor*, as they are highly mobile during their daily activities in search of food or avoid overlapping with the territories of other individuals. This implies that the areas sampled constitute biological corridors for these species to and from Llanganates and Sangay National Parks, especially if we take into account that the distance between the Parks and the points sampled varies between 2 and 8 km.

Considering the analyzed sites, just Rio Encanto and San Jacinto show high numbers of records for *T. pinchaque*, while *T. ornatus* has a higher abundance of records in the localities of Rio Encanto, San Jacinto, and Sacha Llanganates. However, the localities of Cabeceras del Anzu and Boayaku could provide seasonal food sources during the winter season for the bear.

In this context, it is important to emphasize the influence of geography and vegetation cover on the availability of habitat for the above-mentioned species. Thus, the rugged geography and absence of access roads for the expansion of human activities have allowed several areas to maintain important extensions of forest along river basins and mountain ranges that descend from the heights of the National Parks; it is precisely through the river basins and mountains ranges that these large mammals descend at different times, due to heavy rains and low temperatures, as well as in search of new sources of food.

The region between the cities of Baños and Puyo constitutes a biogeographic unit demarcated by the upper Pastaza basin, one of the most humid and rainy places in the Amazon basin, together with the complicated geography of the mountains that rise toward the moorlands of the Llanganates and Sangay National Parks, giving rise to an infinity of ecosystems, habitats, and microhabitats. This region conserves a still underestimated biodiversity.

There are important extensions of natural forests that are currently partially protected, thanks to private initiatives, private reserves, and community reserves. Several of the sampling localities have been the subject of research in the field of herpetology, for example, Cabeceras del Anzu and Sacha Llanganates areas have high diversity and endemism of amphibians with more than 60 species including numerous endemic species to Ecuador [10].

4.2 Threats to biodiversity

4.2.1 Hunting pressure

Localities such as Rio Encanto, San Jacinto, and Sacha Llanganates do not currently present strong hunting pressure, due to the conservation initiatives developed in the area, as well as the control carried out by personnel from the Ministry of Environment in the Río Negro sector and its surrounding communities. However, it is known that until a few years ago, people from Amazonian communities came to the forest areas adjacent to the Llanganates and Sangay Parks to hunt.

Subsistence hunting is the main use that local communities have on wildlife, however, due to the characteristic of the Boayaku and Flor de Bosque villagers' land use, hunting is not considered a threat to wildlife; however, a quantitative study is needed during different times of the year and in the long term to determine these impacts in more detail.

Of all existing species, rodents such *Dasyprocta fuliginosa*, *C. paca*, artiodactyls like *Dicotyles tajacu*, and edentates such *Dasybus novemcinctus* are considered to be the species with the greatest hunting pressure from the communities. It should be noted that there is no evidence of a diversified ethnozoological use of fauna in the communities,

as most of the species are destined for food consumption, and very few of them are used for handicrafts, medicinal purposes, and even less for commercialization in the form of meat or breeding animals.

4.2.2 Habitat loss and alteration

Although the large infrastructure and the expansion of roads, provide facilities for the development of communities and population centers, the pressure on natural ecosystems increases exponentially, as does the risk of extinction of endangered species of flora and fauna. This is the case of the localities in the highlands where the Topo Hydroelectric Project is being implemented a few kilometers from the border of the Llanganates National Park. This same project has promoted the extension of a road toward the Leon River near the junction with San Jacinto River, a few kilometers from the present investigation area, which has led to an increase in grasslands and habitat fragmentation. Furthermore, new hydroelectric projects are planned for the future, such as Abitagua, which will form a reservoir on the provincial border between Tungurahua and Pastaza, affecting the mouth of Rio Encanto and an as yet undetermined area in the only probable zone for implementing an effective corridor between the Llanganates and Sangay National Parks.

On the other hand, in the area of Boayaku and Flor de Bosque, are reported latent threats of mining exploitation and oil expansion, as they are located within Block 28 Petroleum concessions in the south-central Amazon, which puts the water sources and territories of the species recorded in this study at high risk.

5. Conclusion

Field sampling in six localities of the Llanganates-Sangay Corridor shows the presence of macro mammals communities in a good state of conservation, representing areas of use and potential corridor toward the Llanganates and Sangay National Parks. Within the study area, the localities of Rio Encanto, San Jacinto, and Sacha Llanganates, constitute a strategic refuge for highly endangered and typically Andean species such as the Andean tapir *T. pinchaque* and spectacled bear *T. ornatus*; while the lowland localities of Cabeceras del Anzu, Boayaku and Flor de Bosque constitute a refuge area for typical Amazonian species such as the ocelot *Leopardus pardalis*, peccary *Dicotyles tajacu*, jaguarundi *Herpailurus yagouaroundi*, and others.

The six localities analyzed are home to globally threatened mammal populations, but there are numerous species of flora and fauna endemic to the region, so conservation initiatives developed by communities, private stakeholders, and other organizations in the region are an important step toward promoting the creation of larger areas of protection. The study area is presented as a potential ecological corridor for the populations of macro mammals monitored, as it allows the flow and connectivity between the high and low zones. The existence of hydrographic subbasins such as the Anzu within the Llanganates-Sangay Ecological Corridor makes it an important refuge for threatened species of the tropical Andes, whose populations have been drastically reduced in the lower zones, close to the colonization frontier.

Finally, it is essential to develop a monitoring program in the six study localities, increasing the sampling effort and the number of camera traps, including visits during different times of the year, with a view to determining activity patterns, habitat use, and population status, with special emphasis on endangered species. It is also

essential to involve local actors and communities in the planned initiatives, promoting conservation strategies and sustainable use of resources such as community tourism, forest resource management, and agroecology, as alternatives to traditional exploitation of natural resources.

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Conflict of interest

The authors declare no conflict of interest.

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