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First photographic records of puma *Puma concolor* (Linnaeus, 1771) and other terrestrial mammals in Parque Nacional Volcán Irazú, Prusia sector, Costa Rica

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ABSTRACT
Knowledge of mammal composition in Costa Rica's protected areas is fundamental for both community ecology studies and conservation decision-making. We conducted an inventory of terrestrial mammals along eight trails in Parque Nacional Volcán Irazú, Prusia sector (PNVI-Pr) using complementary techniques to provide data for conservation planning. The mammalian inventory of PNVI-Pr includes one large-sized species, puma *Puma concolor*, 13 medium-sized species, and two species and three genera of small-sized mammals. This inventory suggests a rich mammal fauna yet to be fully identified, particularly among rodents and shrews, a pattern commonly observed in montane ecosystems.
Keywords: coyote, felines, mammal fauna, montane forest, puma report

RESUMEN - Primeros registros fotográficos de puma *Puma concolor* (Linnaeus, 1771) y otros mamíferos terrestres del Parque Nacional Volcán Irazú, sector Prusia, Costa Rica
El conocimiento sobre la composición de mamíferos en las áreas protegidas de Costa Rica es fundamental para los estudios de ecología de comunidades y la toma de decisiones en materia de conservación. Realizamos un inventario de mamíferos terrestres a lo largo de ocho senderos del Parque Nacional Volcán Irazú, en el sector Prusia (PNVI-Pr), mediante técnicas complementarias, para aportar información a los planes de conservación. El inventario de mamíferos del PNVI-Pr incluye una especie de talla grande, puma *Puma concolor*, 13 especies de talla mediana, y dos especies y tres géneros de talla pequeña. Este inventario sugiere una rica fauna de mamíferos que aún no ha sido completamente identificada, particularmente entre roedores y musarañas, un patrón comúnmente observado en los ecosistemas montanos.
Palabras clave: bosque montano, coyote, felinos, mastofauna, reporte de puma

The puma or mountain lion, *Puma concolor* (Linnaeus, 1771), also known by the Bribri people as dakòlum (Krohn 2025), is the second largest and most widely distributed felid in the Americas. This opportunistic predator inhabits extensive primary and secondary forests (Durán-Alvarado 2016), and furthermore, demonstrates adapt-

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ability to venture into agricultural and suburban landscapes (Morera-Chacón & Ruiz-Chaves 2017; Ramírez-Álvarez et al. 2021). Although the puma is rarely observed, its distribution includes localities in all seven provinces of Costa Rica, ranging from sea level to the subalpine zone (Wainwright 2007), reaching elevations exceeding 3,400 m a. s. l. (Global Biodiversity Information Facility [GBIF] 2024; iNaturalist 2024). Despite its widespread distribution, this species faces threats such as loss of forest cover, reduction of natural prey, and conflicts with humans (Burgas et al. 2014; Zamzow et al. 2018; Ramírez-Fernández et al. 2023).

Apex predators, such as puma, modify species richness and abundance through predation, affect intraguild competitive relationships, and alter the spatiotemporal behavior of mesopredators (Ritchie & Johnson 2009; Wang et al. 2015; Breviglieri et al. 2017). These interactions shape ecological communities, which may have consequences for regulatory processes such as pest control, disease mitigation, soil stabilization, and biogeochemical cycles (Pauli et al. 2018; Lacher et al. 2019). Knowledge of mammalian diversity and composition, as well as the identification of observation sites, constitutes a preliminary step toward posing questions about community ecology. This knowledge provides a foundation for justifying the implementation of conservation measures.

In Costa Rica, the scientific literature on species richness and composition of terrestrial mammals in montane and subalpine environments is scarce and fragmented (Timm et al. 1998; Chinchilla 2009; Timm & LaVal 2018, Zamzow et al. 2018; González-Tenorio et al. 2021; Salom-Pérez et al. 2021; Elizondo & Cartín-Núñez 2024). In the case of Parque Nacional Volcán Irazú, Prusia sector (PNVI-Pr), mammalian fauna is considered to be of low diversity, primarily due to recent volcanic activity and the highly fragmented landscape surrounding this park. In previous reports preceding this investigation, incidental observations of four mammalian species were documented including coyote *Canis latrans* (Say, 1823), nine-banded armadillo *Dasypus novemcinctus* (Linnaeus, 1758), red-tailed squirrel *Syntheosciurus granatensis* Humboldt, 1811, and variable pocket gopher *Heterogeomys heterodus* (Peters, 1865) (Sistema Nacional de Áreas de Conservación [SINAC] 2008). In this study, we aimed to increase the inventory of terrestrial mammals in PNVI-Pr using complementary techniques to provide information for the development of conservation measures.

The Prusia sector of PNVI covers 54% of the park's total area (2,738 ha) and is situated within a rural-agricultural landscape, with a suburban-to-urban transition occurring less than 10 km from the park's boundaries. Most of the protected area is in the province of Cartago (Cantons of Alvarado, Oreamuno, and Cartago), with a small sector located in San José (Canton of Vázquez de Coronado), between the coordinates 9.949272° -10.010630° N and -83.899573- -83.830999 W (Fig. 1). The altitudinal range of PNVI-Pr extends from 2,300 m a. s. l. to 3,432 m a. s. l., with an annual average temperature varying between 5°C and 12°C and an annual average precipitation ranging from 1,500 mm to 2,400 mm (Instituto Meteorológico Nacional [IMN] 2008; SINAC 2008). This national park features a complex topography with vegetation typical of montane, very humid, and montane pluvial forests (Tosi 1969), among which oak (*Quercus* sp.), alder (*Alnus* sp.), and sage (*Buddleja* sp.) are prominent. However,

there is a notable component of exotic flora including cypress, pine, eucalyptus, and sequoias. Additionally, paramo vegetation is present, primarily comprising grasses, ferns, lichens, and mosses.

Between November 2020 and July 2021, we conducted an inventory of terrestrial mammals along eight trails of PNVI-Pr: principal, La Gruta, Chiverrales, Cabeza de Vaca, El Ahorcado, El Roble, El Puma, and Los Abuelos (Fig. 1). We deployed four camera traps (two Apeman H55 and two Bushnell 119636C) in proximity to water sources and wildlife trails, identified through tracks, to detect the presence of mammals. The Bushnell model employed allowed for only one type of record configuration, either photo or video. Consequently, in the equipment setup, we established the video and photo modes for the two Apeman devices; photo mode for one Bushnell and video mode for the second Bushnell; burst photos of three, videos of 10 s for Apeman and 20 s for Bushnell. The cameras were positioned 0.5 m above ground level, utilizing tree trunks as support, and were relocated after a period of one month. Additionally, we explored the trails of PNVI-Pr during the morning and evening to conduct visual surveys and detect vocalizations and tracks. We identified the observed mammals and their tracks using the field guides by Chame (2003), Wainwright (2007), and Aranda-Sánchez (2012). Small mammals were captured using three Sherman Traps Inc., which were baited with oats and placed within the forest near the principal trail. The captured rodents were identified up to the Genus level using the key by Villalobos-Chávez (2016), and subsequently we released them at their respective capture sites. Finally, during the study period, we surveyed 64 tourists regarding mammal sightings during their visit to PNVI-Pr, and we also inquired with 12 residents about the mammals they commonly observe. In both instances, we provided the respondents with Wainwright's guide (Wainwright 2007) to facilitate taxonomic identification of mammals.

The compiled mammalian inventory of PNVI-Pr includes one large mammal species, 13 medium-sized species, two species and three genera of small-sized mammals (Table 1). For the sole apex predator inventoried, *P. concolor*, we obtained three records in proximity to the Chiverrales (latitude 9.962694; longitude -83.88374; 2,974 m a. s. l.), El Roble (latitude 9.967826; longitude -83.870135 3,019 m a. s. l.), and La Gruta (latitude 9.97038; longitude -83.880; 2,977 m a. s. l.) trails (Fig. 1). The dates and times of the recordings were December 23, 2020, at 21:06 h, February 4, 2021, at 03:41 h, and June 30, 2021, at 15:14 h (Fig. 2). In addition to the puma footprints observed on El Roble trail, one resident surveyed included this large felid as part of the area's mammalian fauna. However, during our surveys within PNVI-Pr, we were unable to sight the species (Table 1).

Six medium-sized mammal species were recorded using camera trapping: jaguarundi *Herpailurus yagouaroundi* (É. Geoffroy St.-Hilaire, 1803), coyote *C. latrans* Say, 1823, gray fox *Urocyon cinereoargenteus* Schreber, 1775, northern raccoon *Procyon lotor* (Linnaeus 1758), common opossum or zarigüeya *Didelphis marsupialis* Linnaeus, 1758, and Dice's rabbit *Sylvilagos dicei* W. P. Harris, 1932. Except for the common opossum, the remaining mammals were also identified through tracks, sightings, vocalizations, or consultation with residents (Fig. 2; Table 1).

Two species of medium-sized mammals were recorded exclusively through sightings: long-tailed weasel *Neogale frenata* (Lichtenstein, 1831) and mexican porcupine *Coendou mexicanus* (Kerr, 1792). Cacomistle *Bassariscus sumichrasti* (Saussure, 1860) was both sighted and heard through its vocalizations. Nine-banded armadillo *D. novemcinctus* was sighted and identified by the surveyed neighbors. Furthermore, based on inquiries conducted with tourists and residents, we included three additional species of medium-sized mammals: tayra *Eira Barbara* (Linnaeus, 1758), margay *Leopardus wiedii* (Schinz, 1821), and white-nosed coati *Nasua narica* (Linnaeus, 1766) (Table 1).

Regarding small mammals, we recorded the presence of red-tailed squirrel *S. granatensis* through camera traps and sightings; additionally, the species was recognized in the surveys. Variable pocket gopher *Heterogeomys heterodus* was both sighted and mentioned by interviewees. Finally, shrew *Cryptotis* sp. was sighted and two genera of cricetid mice, *Peromyscus* and *Reithrodontomys* sp., were captured using Sherman traps (Table 1; Fig. 2).

All eight studied trails exhibited reports of terrestrial mammals. Excluding cricetids and shrews, the highest species richness was observed on the principal trail, with nine species, including mesopredators (coyote, gray fox, northern raccoon, and cacomixtle) and various omnivorous and herbivorous prey species (nine-banded armadillo, mexican porcupine, Dice's rabbit, red-tailed squirrel, and variable pocket gopher). The second highest species richness was recorded on El Roble trail, with six species, which include an apex predator (puma), several mesopredators (coyote, long-tailed weasel, and northern raccoon), and two herbivorous prey species (red-tailed squirrel, and Dice's rabbit). The third highest species richness was observed on El Puma trail, with four species, three of which are mesopredators (jaguarundi, coyote, and northern raccoon) and one an herbivorous prey species (Dice's rabbit; Table 1). These three trails are connected and located in the southeastern sector of PNVI-Pr (Fig. 1).

The terrestrial mammal species inventory of PNVI-Pr increased from four species, as reported by SINAC (2008), to 16 species and three genera (for which species identification could not be achieved), in this study. This result suggests the presence of a rich mammalian fauna has yet to be fully identified, particularly rodents and shrews, as is often the case in montane regions (Geise et al. 2004; Rico-Cernohorska et al. 2020). In comparison with other studies, which were more extensive in time and space, we listed between 60% and 70% of the medium to large-sized mammals reported in other mountainous regions of Costa Rica despite our equipment limitations (González-Tenorio et al. 2021; Salom-Pérez et al. 2021). This result underscores the importance of complementing camera trapping techniques with direct observation, tracking, and surveys in mammalian inventories (Braga et al. 2018).

After more than three decades without any confirmed records—according to SINAC (pers. comm., March 2025)—*P. concolor* is documented for the first time in PNVI-Pr through photographic evidence and footprints obtained during this study. Historical observations of the species consist of anecdotal accounts from retired park rangers, which have been passed down to newer generations of staff. Our records occurred one year after an iNaturalist report of *P. concolor* in Vásquez de Coronado, San José (PNVI-Pr), approximately 1.6 km northeast of the site where a puma was later de-

tected by a camera trap (El Roble trail). It is possible that the recent restoration of that sector of the park is attracting these felines, which increases the likelihood of their detection. This suggests that the puma population in Prusia has not been extirpated, as suggested by one of the residents consulted, and that they are confined in less accessible areas with steep slopes and canyons.

In contrast to coyote, which was present on all trails and easily detected through all techniques utilized, puma was only detected on three trails, primarily through camera trapping. Both species fulfill roles within ecological communities. Coyote contributes to the predation of domestic animals (Crooks & Soulé. 1999; Gehrt et al. 2013), such as cats and dogs present in the national park. This species may also limit granivorous micromammal populations, facilitate seed dispersal (Roehm & Moran 2013; Armenta-Méndez et al. 2020), promote plant recruitment (Bartel & Orrock 2021), and serve as a scavenger (Gerraty et al. 2024). Nevertheless, this dominant mesopredator would only partially fulfill the role of puma as a regulator and community structurer, thereby compromising the equilibrium of PNVI-Pr ecosystems (Avrin et al. 2023).

This investigation also suggests the coexistence of a terrestrial mammal assemblage comprising one apex predator species, *P. concolor*, an obligate carnivore, and eleven mesopredator species with either obligate carnivorous or omnivorous habits (Wainwright 2007; Reid & Gómez-Zamora 2022). These mammalian species may engage in competitive interactions or form part of the diet of this large feline (Ritchie & Johnson 2009; Karandikar et al. 2022). Similarly, the species recorded in this inventory could form part of the diet of the apex and mesopredators (Karandikar et al. 2022; Reid & Gómez-Zamora 2022).

Ecological communities face multiple threats, including habitat loss and climate change, which are anticipated to alter the assemblages of mammals and other vertebrate groups (Segan et al. 2016; Baisero et al. 2020). To mitigate this scenario and preserve the mammalian fauna hitherto reported in the area, the connection of this national park with interurban corridors will be vital (Salom-Pérez et al. 2021). In this context, the Reventado-Agua Caliente Sub-basin Corridor, with an area of 184.5 km^2 (SINAC 2018), could facilitate the movement and genetic viability of puma populations and other inventoried mammals. Additional research will be necessary to understand these interactions, particularly the behavior of mesopredators in relation to puma, tourists, and the fragmented landscape surrounding PNVI-Pr (Wang et al. 2015; Gaynor et al. 2018).

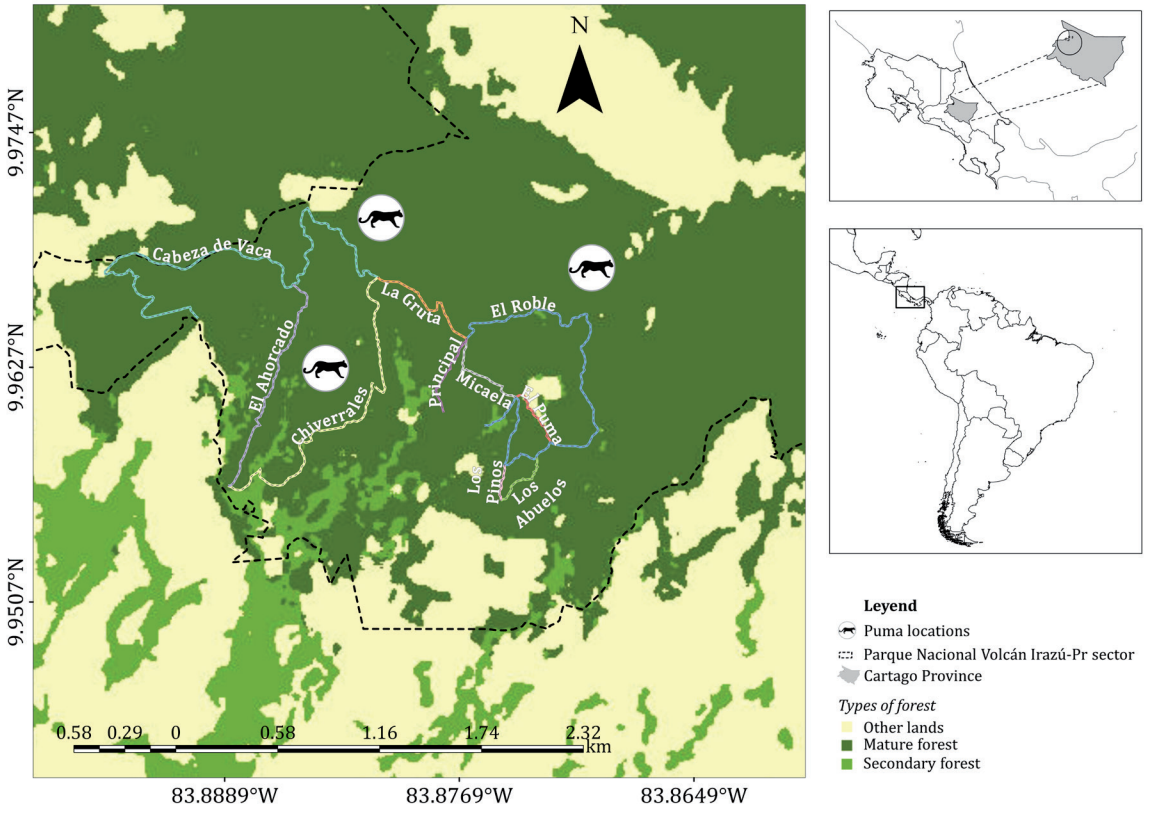

Figure 1. Map of Parque Nacional Volcán Irazú-Pr sector showing the studied trails and the locations where *P. concolor* was recorded. Base map includes forest and land cover data from SINAC, MINAE & Inisefor-UNA (2022).

Figure 2. Part of the inventory of terrestrial mammals recorded on eight trails of Parque Nacional Volcán Irazú-Prusia sector, Costa Rica, 2020-2021. A) *Puma concolor*; B) *Herpailurus yagouaroundi*; C) *Canis latrans*; D) *Urocyon cinereoargenteus*; E) *Procyon lotor*; F) *Sylvilagus dicei*; G) *Didelphis marsupialis*; H) *Syntheosciurus granatensis*; I) *Reithrodontomys* sp.; J) *Peromyscus* sp.; K) *Heterogeomys heterodus.*

Table 1. Classification of the trophic category and group of terrestrial mammals recorded on eight trails of Parque Nacional Volcán Irazú- Pr sector, Costa Rica, 2020-2021.
Trails: CH=Chiverrales, CV=Cabeza de Vaca, EA=El Ahorcado, EP=El Puma, ER=El Roble, LA=Los Abuelos, LG=La Gruta, PR=Principal. Record type: CT=camera trapping, FE=feces, FP=footprints, NA= Not Applicable, SH=Sherman traps, SI=sightings, SU=survey, VO=vocalizations. Conservation status: LC=least concern, NT=near threatened, VU=vulnerable, NA= Not Applicable.

Species	Trail	Record type	Trophic category	Trophic group	Conservation status
Puma concolor	CH, ER, LG	CT, FP, SU	Apex predator	Obligate carnivore	Decreasing, LC
Herpailurus yagouaroundi	EP, LA	CT, SU	Mesopredator	Obligate carnivore	Decreasing, LC
Leopardus wiedii	NA	SU	Mesopredator	Obligate carnivore	Decreasing, NT
Canis latrans	CH, CV, EA, EP, ER, LA, LG, PR	CT, FE, FP, SI, SU, VO	Mesopredator	Omnivore	Increasing, LC
Urocyon cinereoargenteus	CV, LG, PR	CT, FE, SI, SU	Mesopredator	Omnivore	Stable, LC
Neogale frenata	ER	SI	Mesopredator	Obligate carnivore	Stable, LC
Eira barbara	NA	SU	Mesopredator	Omnivore	Decreasing, LC
Procyon lotor	EP, ER, PR	CT, SI, SU, FP	Mesopredator	Omnivore	Increasing, LC
Nasua narica	NA	SU	Mesopredator	Omnivore	Decreasing, LC
Bassariscus sumichrasti	PR	SI, VO	Mesopredator	Omnivore	Unknown, LC
Dasypus novemcinctus	PR	SI, SU	Mesopredator	Omnivore	Stable, LC
Didelphis marsupialis	LA	CT	Mesopredator	Omnivore	Stable, LC
Coendou mexicanus	PR	SI	Prey	Herbivore	Unknown, LC
Sciurus granatensis	ER, PR	CT, SI, SU	Prey	Herbivore	Stable, LC
Sylvilagus dicei	CV, EP, ER, PR	CT, FE, SI, SU, FP	Prey	Herbivore	Decreasing, VU
Heterogeomys heterodus	PR	SI, SU	Prey	Herbivore	Increasing, LC
Peromyscus	PR	SH	Prey	Herbivore	NA
Reithrodontomys	PR	SH	Prey	Herbivore	NA
Cryptotis	PR	SI	Prey	Omnivore	NA

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