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Big cats (Carnivora, Felidae) still walking in Sierra de las Minas Biosphere Reserve: a forgotten Jaguar Conservation Unit in northeastern Guatemala

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Abstract. The detection of Jaguars, *Panthera onca* (Linnaeus, 1758), and Pumas, *Puma concolor* (Linnaeus, 1771), in the Sierra de las Minas Biosphere Reserve, northeastern Guatemala, represents a pivotal step in understanding the distributional range of these apex predators in the country. Using camera traps, we documented 12 independent records of Puma and one of Jaguar, including the remarkable presence of Jaguars at elevations above 2000 m, which suggests new directions for ecological research and high-altitude conservation strategies. These findings have important implications for the long-term survival and conservation of these species within Jaguar Conservation Units, emphasizing the necessity of effective management measures that promote functional connectivity through habitat preservation and restoration, especially for populations outside the Mayan Biosphere Reserve.

Key words. Conservation, elevation profile, Jaguar, functional connectivity, Puma

Trujillo LA, Mármol-Kattán A, Abugarade C, Rivera-Sandoval A, Chaluleu-Baeza C, Leonardo R, Mansilla D, Trinidad A, Quijivix C, Martínez I, Escobar C, Paz R, Ramírez A, Escobar-Anleu BI, Escobar R, García-Anleu R (2025) Big cats (Carnivora, Felidae) still walking in Sierra de las Minas Biosphere Reserve: a forgotten Jaguar Conservation Unit in northeastern Guatemala. Check List 21 (3): 544–551. https://doi.org/10.15560/21.3.544

INTRODUCTION

Jaguars (*Panthera onca* (Linnaeus, 1758)) and Pumas (*Puma concolor* (Linnaeus, 1771)) coexist in sympatry throughout their Neotropical range (Scognamillo et al. 2003; Ávila-Najera et al. 2020). As apex predators, both species play a crucial role in maintaining ecosystem balance, requiring extensive territories to sustain viable populations (Tobler et al. 2018). However, across their distribution, these habitats have experienced significant range contractions and population isolation, mainly due to anthropogenic pressures such as habitat loss, fragmentation, and hunting (Sanderson et al. 2002; Quigley et al. 2023).

In Guatemala, Jaguars and Pumas have primarily been documented within the Mayan Biosphere Reserve (MBR) in the Petén department (Moreira et al. 2007; Ruano et al. 2010; Maffei et al. 2011; Soto-Shoender and Main 2013; García-Anleu et al. 2015; Tobler et al. 2018; García-Anleu et al. 2020; Gaitán et al. 2021, 2022a, 2022b; Calderón et al. 2022, 2024). However, additional records document their presence in other departments, including Izabal, Alta Verapaz, Baja Verapaz, Quiché, Sacatepéquez, and Suchitepéquez (Escobar-Anleu et al. 2017; Escobar-Anleu 2019; GBIF 2024a, 2024b). Despite numerous research and conservation initiatives targeting these species, the primary focus has been on Jaguars. These efforts encompass a wide range of studies, addressing distribution patterns, ecological behaviors, population dynamics, and public perceptions (Moreira et al. 2007; Ruano et al. 2010; Maffei et al. 2011; Soto-Shoender and Main 2013; García-Anleu et al. 2015; Escobar-Anleu et al. 2017; Tobler et al. 2018; García-Anleu et al. 2020; Gaitán et al. 2021, 2022a,

OPEN ACCESS

Academic editor: Diego Astú
Received: 29 July 2024
Accepted: 29 March 2025
Published: 15 May 2025

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2022b; Calderón et al. 2022, 2024). Nonetheless, significant information gaps remain within the Guatemalan territory (Moreira et al. 2007; Escobar-Anleu 2019).

The establishment of Jaguar Conservation Units (JCUs) was driven by the need to protect Jaguar populations across their extensive range, spanning from the southern United States to Argentina (Sanderson et al. 2002). This initiative identified 51 priority JCUs, underscoring the importance of understanding ecological processes essential for the species' long-term survival (Sanderson et al. 2002; Zeller 2007). These units represent robust habitats capable of supporting viable Jaguar populations and are characterized by sufficient prey abundance and diversity (Nijhawan 2012). For optimal reproductive success, each JCU should ideally sustain a minimum of 50 reproductive-age individuals, a target critical to maintain population viability and genetic diversity across their transboundary habitats (Zeller and Rabinowitz 2013).

One of Guatemala's designated JCUs is the Sierra de las Minas Biosphere Reserve (SMBR), a 130 km mountain range located between the Motagua and Polochic valleys in northeastern Guatemala. The SMBR, characterized by elevations from sea level to 3015 m (Matson et al. 2016), hosts a wide variety of ecosystems shaped by significant topographic variability, each with distinct characteristics and plant assemblages (IARNA-URL 2018). Spanning roughly 2400 km^2, the SMBR also encompasses Central America's largest extent of cloud forest, underscoring its critical role in regional biodiversity conservation (Matson et al. 2016).

To date, no published records, museum specimens, or media evidence confirm the presence of Jaguars and Pumas in the SMBR, highlighting a significant gap in current knowledge. This study addresses this gap by compiling recent occurrence records for both species within the reserve. We further discuss the implications of these findings for the management of JCUs and proposed conservation corridors critical to the long-term survival of these apex predators.

METHODS

We collected the data presented in this study using camera traps, an essential component of the SMBR biological monitoring program. These devices have proven effective in capturing both photographic and video content, offering a non-intrusive method for observing and documenting wildlife activity and distribution throughout the reserve (Tobler et al. 2008; Chaluleu 2020).

To assess the presence of Jaguars and Pumas, we used presence-only data from the biological monitoring program datasets of Fundación Defensores de la Naturaleza (FDN; GBIF 2025). Notably, the Global Biodiversity Information Facility (GBIF 2024a, 2024b) lacked records, museum specimens, or other documented evidence of these species within the SMBR. Additionally, no scientific publications documented the occurrence of these felids in the reserve. Despite these data gaps, our collaborative efforts resulted in the identification of 13 independent records, including 12 for Pumas and one for Jaguars.

We generated a map of the study area using ArcGIS Pro v. 3.2.2, integrating several key data layers. These included the delineation of protected areas in Guatemala, sourced from the Guatemalan System of Protected Areas (SIGAP), historical jaguar and puma occurrence records with coordinates from the Global Biodiversity Information Facility (GBIF), and a data layer on JCUs (Sanderson et al. 2002) and proposed connectivity corridors (Rabinowitz and Zeller 2010).

To contextualize our observations of jaguars and better understand the species' elevational distribution, we constructed an elevation profile using data from across the species' range, sourced from GBIF (GBIF 2024a). We retrieved records by searching for "*Panthera onca*", including only those with geographic coordinates associated with a specific collection specimen, photograph, or observation. This search resulted in a total of 2925 specimens and occurrence points (Figure 1).

RESULTS

Between 2015 and 2023, one Jaguar and 12 Pumas were recorded in the highly humid tropical montane and premontane forests on the northwestern slope of the Sierra de las Minas Biosphere Reserve (SMBR) (IARNA-URL 2018; Figure 1). Notably, on 3 December 2019 at approximately 14:00 hours a Jaguar was observed in a preserved cloud-forest fragment in Santa Catarina Arriba, El Progreso department, at an elevation of 1994 m a.s.l. Unfortunately, no photographic or video evidence was captured during the brief observation (Figure 1).

***Panthera onca* Linnaeus, 1758**
Figure 2A

New record. GUATEMALA — Baja Verapaz • Ribacó, Purulhá, Reserva de la Biosfera Sierra de las Minas; 15.1036, −089.9550; 2243 m a.s.l.; 24.VI.2015; FDN obs.; camera trap set in a preserved clouded-forest fragment; 1 ♀, adult; video recording (Supplementary Materials Video S1).

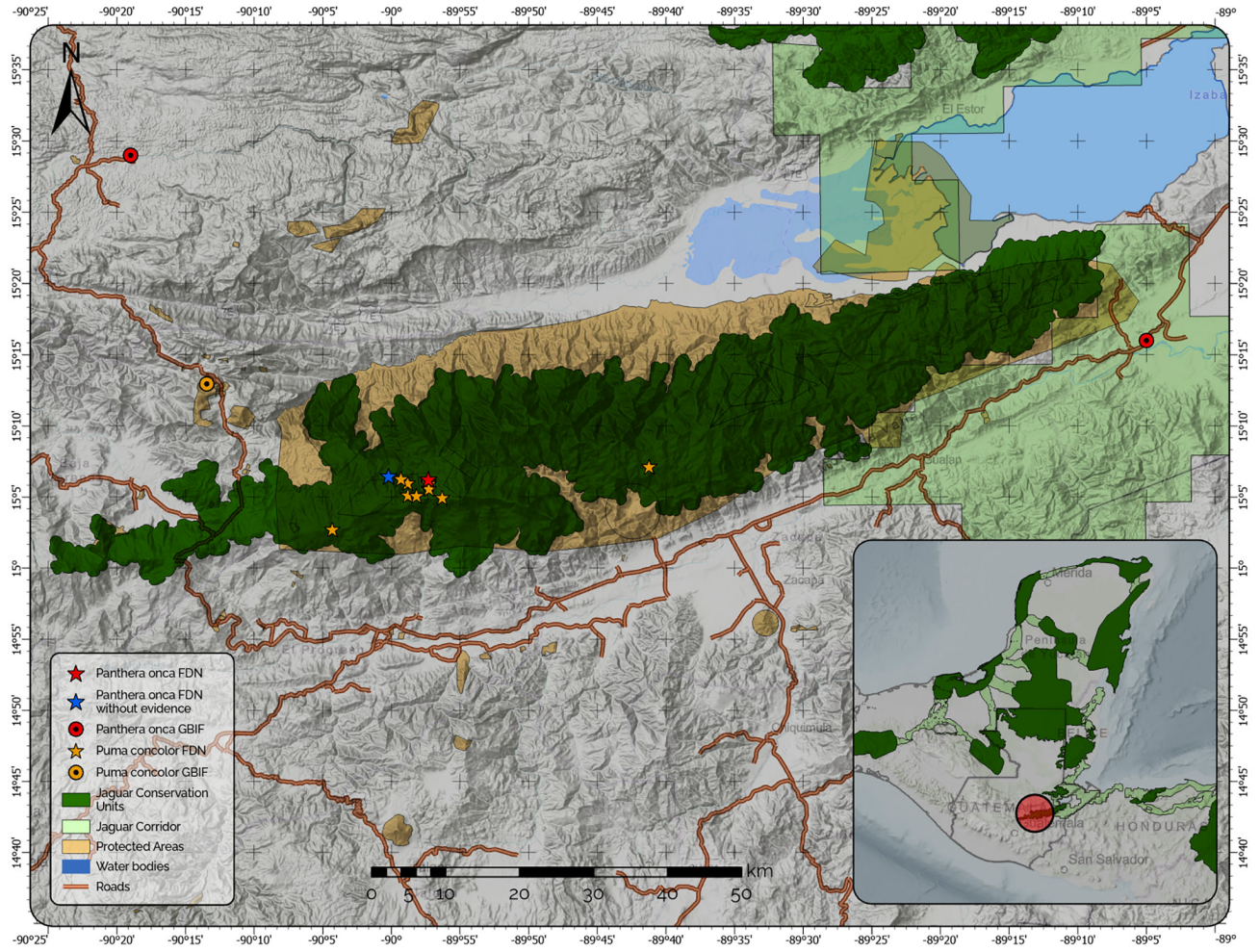

Figure 1. Location of Jaguars (*Panthera onca* (Linnaeus, 1758)) and Pumas (*Puma concolor* (Linnaeus, 1771) records in the Sierra de las Minas Biosphere Reserve (SMBR) in relation to Jaguar Conservation Units (JCU) in Guatemala and proposed connectivity corridors. Records reported in this contribution are shown (red and blue stars for Jaguars and orange stars for Pumas) as well as previous records gathered from GBIF (red dots for Jaguars and orange dots for Pumas).

Identification. The Jaguar is a large, powerful feline characterized by a robust head, golden-yellow to sandy-brown dorsal fur adorned with black rosettes, a white-spotted underside, a short tail, and stocky legs. It is distinguishable from other Neotropical felids, such as Puma, by its larger size and more heavily built body and its black rosettes (Seymour 1989; Reid 2009).

Distribution. The elevation profile analysis of Jaguar occurrences revealed that most records (87.7%) are concentrated between 0 m and 500 m, with fewer than 1% documented above 2000 m (Figure 3). These records, encompassing 426 localities from the southern United States to Argentina (GBIF 2024a), underscore the rarity of high-altitude occurrences. Notably, our study provides the first high-elevation Jaguar record in Guatemala, suggesting that the species' elevational and ecological range in the country may extend beyond previous knowledge. This observation is particularly notable, as it falls within the top 1% of records identified between 2000 m and 3000 m in the species' elevation profile (Figure 3).

Puma concolor Linnaeus, 1771

Figure 2B

New records. GUATEMALA — **Baja Verapaz** • Sinaja, Purulhá, Reserva de la Biosfera Sierra de las Minas; 15.0453, −090.0717; 2594 m a.s.l.; N/A.2021; FDN obs.; camera trap set in a preserved cloud-forest fragment; 1 sex ind., adult; photographic record • Ribacó, Purulhá Reserva de la Biosfera Sierra de las Minas; 15.1008, −089.9551; 2296 m a.s.l.; 16.VII.2016; FDN obs.; camera trap set in a preserved cloud-forest fragment; 1 sex ind., adult; photographic record • Purulhá Reserva de la Biosfera Sierra de las Minas; 15.0997, −089.9802; 2211 m a.s.l.; 12.VI.2021; FDN obs.; 15.0854, −089.9799; 2331 m a.s.l.; 31.III.2021; FDN obs.; 15.0847, −089.9695; 2311 m a.s.l.; 31.III.2021; FDN obs.; camera trap set in a preserved cloud-forest fragment; 1 ♂, adult; video recordings (Supplementary Materials Video S1) • Ribacó, Purulhá, Reserva de la Biosfera Sierra de las Minas; 15.1045,

Figure 2. A. Jaguar (*Panthera onca* (Linnaeus, 1758)) and **B.** Puma (*Puma concolor* (Linnaeus, 1771)) records from Sierra de las Minas Biosphere Reserve (SMBR), Guatemala.

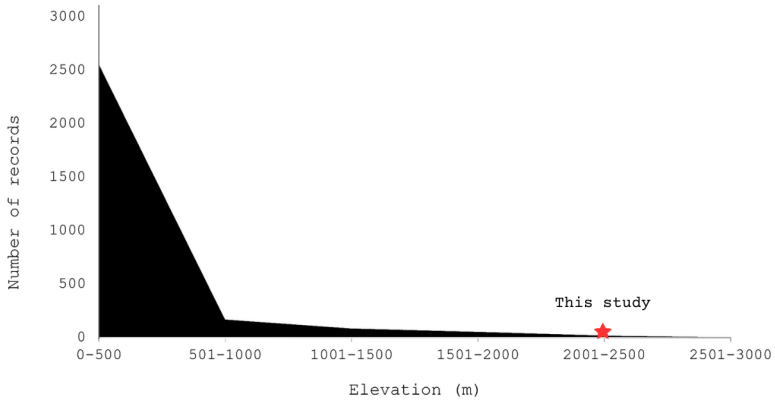

Figure 3. Elevation profile of Jaguars (*Panthera onca* (Linnaeus, 1758)) across their distributional range, based on occurrence records obtained from the Global Biodiversity Information Facility (GBIF 2024a, 2024b) and the biological monitoring program datasets of Fundación Defensores de la Naturaleza (FDN; GBIF 2025).

–089.9884; 2072 m a.s.l. 13.VIII.2022; FDN obs.; 15.1041, –089.9554; 2351 m a.s.l. 10.V.2023; FDN obs.; camera traps set in a preserved cloud-forest fragment; 1 ♂, adult; video recording (Supplementary Materials Video S1). — **El Progreso** • San Agustín Acasaguastlán, Reserva de la Biosfera Sierra de las Minas; 15.0826, –089.9383; 2597 m a.s.l.; 4.VI.2021; FDN obs.; 15.0929, –089.9544; 2507 m a.s.l.; 13.VI.2023; FDN obs.; 15.0989, –089.9544; 2434 m a.s.l..; 13.VI.2023; FDN obs.; camera traps set in a preserved cloud-forest fragment; 1 ♀, adult; video recording/ photographic records (Supplementary Materials Video S1) — **Zacapa** • San Lorenzo, Reserva de la Biosfera Sierra de las Minas; 15.1191, –089.6868; 2195 m a.s.l.; 10.VII.2023; FDN obs.; 15.1188, –089.6872; 2181 m a.s.l.; 11.VII.2023; FDN obs.; camera traps set in a preserved cloud-forest fragment; 1♂, adult; photographic record.

Identification. The Puma is a powerful and agile felid characterized by a slender, uniformly colored body, long legs, a small head, and a long, cylindrical tail, all of which are adapted for speed. Unlike other Neotropical cats, the Puma lacks distinctive rosettes; however, cubs are born with spots that fade as they mature. Similarly, the Jaguarundi (*Herpailurus yagouaroundi* (É. Geoffroy Saint-Hilaire, 1803)) also lacks rosettes, but it is much smaller size and distinct body proportions make confusion between the two species unlikely (Currier 1983; Reid 2009).

Individual differentiation. Twelve independent records of Pumas, attributed to six distinct individuals, were documented across three separate microbasins. Individual differentiation was based on criteria such as date, time, sex, unique identifying marks, linear distance between records, and an 80 km^2 buffer (5 km radius). These buffers, based on the maximum home range reported for the species in Neotropical ecosystems (de la Torre et al. 2017), supported the distinction of individuals within each microbasin (Supplementary Materials Video S1).

DISCUSSION

The occurrence of Jaguars and Pumas across the SMBR provides critical insights into the distribution of these apex predators in the region. Thirteen independent records, including one Jaguar and six distinct Puma individuals, were documented across three separate microbasins. These findings contribute to a broader understanding of the ecological range of both species in Guatemala, with their presence in tropical montane

and premontane forests. The observation of Jaguars at elevations exceeding 2000 m suggests that the species' elevational limits may be more expansive than previously recognized, emphasizing the need for further investigation into their habitat use and the conservation implications of these higher-elevation occurrences.

Pumas are commonly reported in tropical montane and premontane ecosystems, while Jaguars have historically been associated with lowland regions dominated by tropical humid ecosystems. However, occasional records of Jaguars at elevations exceeding 2000 m have been documented (GBIF 2024a). Both Jaguars and Pumas exhibit wide altitudinal range distributions, with Jaguar records ranging from sea level to 3000 m and Puma records extending up to 4900 m (Brown and Lopez-Gonzalez 2001; Sunquist and Sunquist 2002; GBIF 2024a, 2024b).

In addition to the Jaguar and Puma records, we have photographed or video-recorded 24 other species that are known to be part of the diet of these felids: Class Mammalia: Perissodactyla: *Tapirus bairdii* (Gill, 1865); Artiodactyla: *Mazama temama* (Kerr, 1792), *Odocoileus virginianus* (Zimmermann, 1780), *Pecari tajacu* (Linnaeus, 1758); Carnivora: *Nasua narica* (Linnaeus, 1766), *Potos flavus* (Schreber, 1774), *Procyon lotor* (Linnaeus, 1758), *Conepatus semistriatus* (Boddaert, 1785), *Spilogale angustifrons* (Howell, 1902), *Leopardus pardalis* (Linnaeus, 1758), *Leopardus wiedii* (Schinz, 1821), *Urocyon cinereoargenteus* (Schreber, 1775), *Bassariscus sumichastri* (Saussure, 1860), *Galictis vittata* (Schreber, 1776), *Mustela frenata* (Lichtenstein, 1831); Primates: *Alouatta pigra* (Lawrence, 1933); Rodentia: *Cuniculus paca* (Linnaeus, 1766), *Dasyprocta punctata* (Gray, 1842); Cingulata: *Dasypus novemcinctus* (Linnaeus, 1758); Xenarthra: *Tamandua mexicana* (Saussure, 1860); Lagomorpha: *Sylvilagus floridanus* (J.A. Allen, 1890); Marsupialia: *Didelphis marsupialis* (Linnaeus, 1758); Class Aves: Galliformes: *Crax rubra* (Linnaeus, 1758), *Penelope purpurascens* (Wagler, 1830) (Chinchilla 1997; Nuñez et al. 2000; Estrada 2008; Foster et al. 2010; Gómez-Ortiz and Monroy-Vilchis 2013; Ávila-Nájera et al. 2018; Chaluleu Baeza 2020). These high levels of prey richness indirectly indicate the suitability of habitat within the SMBR, providing essential resources for the subsistence of these species.

In Guatemala, five JCUs are recognized, three of which are designated as transboundary areas designed to connect large territories with suitable habitats across different countries (Sanderson et al. 2002). These include the Selva Maya, which connects a significant portion of the Mayan jungle spanning Guatemala, Mexico, and Belize; Montes Azules/Sierra del Lacandón, linking Sierra Lacandona in Mexico with Sierra del Lacandón in Guatemala; the Maya Mountains, connecting a mountain range in the southern MBR between Guatemala and Belize; Sierra de Santa Cruz; and the Sierra de las Minas Biosphere Reserve (Sanderson et al. 2002; Calderón et al. 2022).

Currently, all identified JCUs in Guatemala face critical threats, leading to habitat loss and fragmentation (IARNA-URL 2022; CONAP and INAB 2023; Calderón et al. 2022, 2024). These threats include cattle ranching, agricultural expansion, monoculture plantations, hunting, and illegal activities such as forest fires and human encroachment into protected areas (Sanderson et al. 2002; IARNA-URL 2022; CONAP and INAB 2023; Quigley et al. 2023). Despite these pressures, Selva Maya and Montes Azules/Sierra del Lacandón still contain large, forested areas that provide suitable habitat for jaguar conservation. Similarly, the Sierra de las Minas Biosphere Reserve retains a significant portion of suitable habitat, though it is increasingly isolated. In contrast, Sierra de Santa Cruz and the Maya Mountains have undergone severe habitat contraction, leaving almost no suitable habitat for species conservation (IARNA-URL 2022; CONAP and INAB 2023; Calderón et al. 2022, 2024).

Genetic studies of Jaguar in Mesoamerica have highlighted Izabal, in northeastern Guatemala, as a critical zone for Jaguar connectivity (Rabinowitz and Zeller 2010; Wultsch et al. 2016a). To sustain both structural and functional connectivity among JCUs, several corridor proposals have been developed (Sanderson et al. 2002; Rabinowitz and Zeller 2010; Calderón et al. 2022). These proposals aim to establish pathways that facilitate movement between distinct JCUs, ensuring gene flow and reducing the risk of population isolation (Rabinowitz and Zeller 2010). From these corridor proposals, two primary conservation strategies have emerged: preventing habitat loss and mitigating human-induced pressures within both continuous and fragmented suitable areas. The goal of these strategies is to halt population declines and reduce the risk of extirpation resulting from landscape fragmentation (Rabinowitz and Zeller 2010; Calderón et al. 2022, 2024).

Maintaining functional connectivity is critical for the long-term viability of Jaguar and Puma populations in Guatemala. However, efforts to manage connectivity within the country are significantly hindered by the lack of localized assessments regarding the status of existing populations and their interconnectivity (Calderón et al. 2024). On a broader scale, available data suggests that populations across Central America exhibit low levels of gene flow and genetic admixture (Wultsch et al. 2016a, 2016b). Factors that facilitate jaguar movement and gene flow include forested landscapes and water sources, while human activities negatively impact connectivity (Calderón et al. 2022, 2024). As a result, JCUs serve as critical reservoirs of high-quality habitat for both Jaguars and Pumas in the country. It is therefore imperative to maintain strong connectivity within the largest JCUs and manage the limited connectivity among smaller units, such as the Sierra de las Minas Biosphere Reserve.

This underscores the urgent need for targeted conservation measures to address anthropogenic threats and promote habitat preservation and restoration. Ensuring the long-term viability of jaguar and puma

populations in the SMBR is critical. Additionally, fostering connectivity between the Sierra de las Minas Biosphere Reserve and the Sierra de Santa Cruz is vital for restoring the functional connectivity of smaller JCUs in Guatemala, as well as for conserving jaguar and puma populations outside the MBR. Ongoing monitoring of these populations within the SMBR is essential for accurately assessing their status and informing the development of effective, long-term conservation strategies.

ACKNOWLEDGEMENTS

We extend our heartfelt thanks to all the funders of the biological monitoring activities in the Sierra de las Minas Biosphere Reserve. Special recognition goes to the U.S. Agency for International Development (USAID) in Guatemala through the initiatives Climate, Nature, and Communities in Guatemala, and the USAID Guatemalan Biodiversity Project; Oro Verde through the Cuencas Verdes and Bosques II projects; the U.S. Fish and Wildlife Service (USFWS) through the NMBCA initiative; and Coca-Cola. A special thanks to the Portal de Biodiversidad de Guatemala for their support to upload data to GBIF. We are also immensely grateful to all the field assistants, with special recognition to: Nery Jurado, Israel Alvizures, Alex Méndez, Mario Ramos, Antonio Ortiz, Hermelindo García, Jairo Vargas, Oscar René Hernández, Daniel González, José Miguel Girón, Mynor Alexander García Cun, Vicente Caal, Eduardo Mayén, Lourdes Ordoñez, Marvin Ramiro Ordoñez, Mélzar Pérez, Miguel Ángel Pérez Ixtecoc, Hermelindo Pérez Básquez, Iván Soberanis, Edin Rodriguez, Mario Caal, Alfredo Eduardo Chajón, Salvador Flores, Edin Alvizures, Oscar Raúl Hernandez, Abel Antonio Méndez, Nelson Fajardo, José Otoniel Leiva, Edwin Chacón, Henry Perdomo, Erik Cordón, Ervin Chacón, Hanswer Gómez, William Chacón, Walter Gutierrez, Miguel Hernandez, Wilmer Martínez, Brayan Perdomo, Darlin Adolfo Najera, Frayan Barrientos, Hamilton García, Rigoberto Chacón, Ruben Xicol, Jorge Cholom, Marlen San José, Jorge Sierra, Javier Cholom, José Angel, Adolfo Veliz, Ludwin Ical Bol, Wilber Rodriguez Molina, Alex Del Cid, Bacilio Alonzo, Héctor Mejía, Erick Cahuec, Antonio López, Marcos Cacao, Damián Barillas, Ludwin Villatoro, Lester Hernández, Gerrit Hartmann, and Jorge Jiménez. Finally, we would like to extend our gratitude to WCS Guatemala, WWF Mesoamérica, and Panthera Guatemala for their invaluable partnership in our biological monitoring activities and conservation efforts. Many thanks to the reviewers and editors for their valuable comments and suggestions to improve our contribution.

ADDITIONAL INFORMATION

Conflict of interest

Authors declare that no competing interests exist.

Ethical statement

No ethical statement is reported.

Funding

This publication is based upon work supported by the United States Agency for International Development under award number (Cooperative agreement no. 72052023CA00006).

Author contributions

Conceptualization: LAT. Data curation: LAT, AMK. Investigation: LAT, AMK, CA, CCB, RL, DM, AT, CQ, IM, CE, RP, AR, BIEA, RE, RGA. Visualization: LAT, AMK, ARS. Writing – original draft: LAT. Writing – review and editing: LAT, AMK, CA, CCB, RL, DM, AT, CQ, IM, CE, RP, AR, BIEA, RE, RGA. Visualization: LAT, AMK, ARS.

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Data availability

All data supporting the findings of this study are included in the main text and supplementary materials.

Supplementary materials

Database, video, and photographic evidence of *Panthera onca* and *Puma concolor* available at https://doi.org/10.6084/m9.figshare.28752368

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