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ORIGINAL ARTICLE

Endemic bats (Mammalia: Chiroptera) of Colombia: State of knowledge, distribution, and conservation

Héctor E. Ramírez-Chaves[1, *], Elkin A. Noguera-Urbano[2, 3], Darwin M. Morales-Martínez[4], Danny Zurc[3, 5], Andrés Felipe Vargas-Arboleda[6], Hugo Mantilla-Meluk[3, 6]

Edited by
Juan Carlos Salcedo-Reyes
(salcedo.juan@javeriana.edu.co)

1. Departamento de Ciencias Biológicas, Universidad de Caldas, and Centro de Museos, Museo de Historia Natural, Universidad de Caldas, Calle 65 # 26-10, Manizales, Colombia

2. Instituto de Investigación de Recursos Biológicos, Alexander von Humboldt. Avenida Paseo Bolívar (Circunvalar) 16-20, Bogotá, D.C., Colombia.

3. Sociedad Colombiana de Mastozoología. Bogotá, Colombia.

4. Grupo de Fauna, Programa de Ecosistemas y Recursos Naturales Instituto Amazónico de Investigaciones científicas SINCHI.

5. Museo de Ciencias Naturales de La Salle, Instituto Tecnológico Metropolitano, Calle 54A # 30-01, Medellín, Colombia.

6. Centro de Estudios de Alta Montaña (CEAM), Colección de Mamíferos Universidad del Quindío (CMUQ).

* hector.ramirez@ucaldas.edu.co

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Abstract

Colombia, with 209 species, is one of the richest countries in terms of bat diversity. This high bat diversity is comprised in nine families and 72 genera. A total of eight species of the families Emballonuridae (n = 1) and Phyllostomidae (n = 7) are listed as endemic to the country. In spite the relevance of Colombia in bat diversity, little is known of these endemic species which are mostly known from the type locality (n = 4), whereas for others (n = 2), their taxonomic status is uncertain. Here, available information of endemic bats from Colombia is compiled, and new information on their distribution and conservation is provided. The most included species in publications including the original description (n = 15) was *Lonchorhina marinkellei*. The only distribution pattern observed for the species evaluated was for *Carollia monohernandezi* and *Vampyressa sinchi* that might overlap distributions in the eastern slopes of the Eastern Cordillera. Most endemic species are from the Andean and inter-Andean regions of the country (n = 6). At national level, there are no endemic species in any threatened category; however, at least one species (*Lonchorhina marinkellei*) is considered as Vulnerable (VU) and one (*Saccopteryx antioquensis*) as Endangered (EN) by the International Union for Conservation of Nature - IUCN

Keywords: Andes; Emballonuridae; Phyllostomidae; South America; threaten category.

Introduction

Species restricted to geographic units are recognized as endemic (Stattersfield *et al*., 1998), and areas of endemism are diagnosed by shared distributional boundaries of at least two endemic species (Morrone 1994). The characterization of endemic species is a priority, due to that their persistence along the time requires immediate conservation actions. Bat (Mammalia: Chiroptera) diversity in Colombia comprises almost 40 % of the total of the mammalian species recorded in the country (Ramírez-Chaves *et al*., 2016). Probably, bats are the most frequently studied mammalian group in

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Colombia; however, more emphasis has been done for phyllostomid bats (Mantilla-Meluk *et al*., 2009). The study of bats in the last decades has been growing and the richness of species recorded for the country has increased from 151 confirmed species in 1986 (Cuervo-Díaz *et al*., 1986) to 169 in 2000 (Alberico *et al*., 2000), 198 in 2013 (Solari *et al*., 2013), and 205 in 2016 (Ramírez-Chaves *et al*., 2016).

Recent updates have listed a total of 209 bat species comprised in 72 genera and 9 families (Sociedad Colombiana de Mastozoología 2017; Ramírez-Chaves *et al*., 2018). For this, Colombia occupies the first position in phyllostomid richness (Mantilla-Meluk *et al*., 2009), and the second in emballonurids (Mantilla-Meluk *et al*., 2014a). Interestingly, considering the high bat diversity of Colombia, only eight species are endemic to the country (Ramírez-Chaves *et al*., 2018). The first endemic bat of Colombia (*Lonchorhina marinkellei*: Phyllostomidae) was described 41 years ago (1978), whereas the most recent endemic bat (*Lonchorhina mankomara*) was described in 2016 (Mantilla-Meluk & Montenegro, 2016).

Available information on bats of Colombia is scarce, and this is especially true for endemic species. The information on endemic bats of Colombia is disperse in the literature, and little attention has been paid to these species, despite their restricted distribution, and that almost nothing is known about their biology or systematics. For example, four endemic bats are known only from the type locality (*C. monohernandezi*, *Lonchorhina mankomara*, *L. marinkellei*, *S. mistratensis*: Phyllostomidae), and two of them (*C. monohernandezi* and *S. mistratensis*) are currently known only from the holotype (Contreras Vega & Cadena, 2000; Zurc & Velazco, 2010). In another case, some species are only known from less than five specimens (e.g. *Vampyressa sinchi*; Tavares *et al*., 2014). The aim of this manuscript is to present updated information of the state of knowledge, distribution, research priorities and conservation of the endemic bats of Colombia.

Materials and methods

State of knowledge

Information from published literature is gathered since the first Colombian endemic bat species description in 1978 until 2018. In each study, information on the following categories used to establish the state of knowledge of endemic mammals of Colombia was searched: Publication type (Journal article, Conference proceedings, Book chapter, Book, Thesis, Conference paper), Relevance in the study (Main, Secondary), Anatomy and morphology, Taxonomy and Systematics, Biogeography/distribution and records, Threats and relationships with humans/Conservation (Threats, Conservation, Cultural aspects), Ecology and Natural History (Habitat use, Diet, Behavior,

Abundance, Reproduction), Genetics, and Generalities (Compilation). The key words used for the searches included the names of each endemic species registered (*Anoura carishina, Anoura cadenai, Carollia monohernandezi, Lonchorhina marinkellei, Lonchorhina mankomara, Saccopteryx antioquensis, Sturnira mistratensis*, and *Vampyressa sinchi*) and "Colombia". When a paper covered different topics, each topic was considered separately.

Distribution

Specimens housed in Colombian museums and natural history collections were reviewed, including the Instituto de Investigaciones Biológicas Alexander von Humboldt, Villa de Leyva (IAvH), Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá (ICN), Colección Teriológica, Universidad de Antioquia, Medellín (CTUA, previously known as MUA in reference to Javier Muñoz Arango, the former professor in charge of those collections at the Universidad de Antioquia), and Museo de Historia Natural, Universidad del Cauca, Popayán (MHNUC). Information from publications was also obtained. The area of occupancy (AOO; IUCN 2012) was calculated for each species overlapping the records by a four-square kilometer grid, and the proportion of endemic bats by municipality, department and ecoregion was reported.

The identification of areas of endemism was explored based in these eight bat species. An area of endemism is a group of geographic units that share at least two species (geographic synapomorphy; Morrone, 1994). A method used to identify areas of endemism is the Parsimony Analysis of Endemicity (PAE; Rosen, 1988), which joins sets of geographic units based on geographic synapomorphies (Morrone, 1994). Parsimony Analysis of Endemicity is an insightful method for inferring historical patterns as the areas of endemism (Nihei, 2006). Therefore, a binary matrix was built by coding the presence (1) or absence (0) of the endemic species in ecoregions (Olson *et al*., 2001), intersecting the records with the eco-region maps. A hypothetical area coded by zeros was included to root the cladogram (Morrone, 1994). The matrix was processed applying a PAE (Morrone, 1994) using a heuristic search option, 100 trees to keep, random seed 20, Multiple TBR+TBR and Fast optimization in NONA (Goloboff, 1998), and Winclada (Nixon, 2000).

Additionally, ecological niche models of four endemic bats were proposed (*Anoura cadenai, A. carishina, L. marinkellei* and *V. sinchi*), which were used to identify their potential distribution. Potential distributions of species with low sample sizes can be used to identify unknown populations and distributional areas (Pearson *et al*., 2007). The ecological niche models were built using Maxent 3.4.0 (Phillips & Dudík, 2008; Phillips *et al*., 2017) as implemented by the 'dismo' package (R Core Team, 2016; Hijmans *et al*., 2017) using random seed. The four remaining endemic bats were

characterized by the small number of records (n ≤ 2); therefore, the delete-one jackknife modeling approach by Pearson *et al*. (2007), called "n - 1 jackknife", was used. Only occurrence data identified at the specific level and with longitude-latitude data was used. All occurrence data were verified geographically and taxonomically following the suggestions by Chapman (2005). As predictors, the set of 19 bioclimatic variables (30 arc-seconds (~ 1 km) was used, obtained from the WorldClim database (www.worldclim.org ver. 2.0; Fick & Hijmans, 2017). Logistic output format was used to describe the probability of presence (Phillips & Dudík, 2008), it is a continuous habitat suitability range between 0 (unsuitable) and 1 (the most suitable). Lineal, quadratic and product features were applied as well as other Maxent settings by default and made multiple predictions per species with one of the records excluded in each case, assessing the model's performance by testing the ability of the model to predict the excluded locality under a statistical significance (Binomial test) (Pearson *et al*., 2007). The lowest predicted value (lowest presence threshold, LPT) associated with any of the observed presence records was used to test the models (Pearson *et al*., 2007; $P < 0.05$). It represents the lowest value of the prediction for any of the pixels that correspond to the localities used in calibrating the model. The threshold to convert the ecological niche models maps from suitability indices to presence/absence was applied.

Results

Endemic bats of Colombia have been poorly studied. The species that appears in a larger number of publications is *Lonchorhina marinkellei* (n = 15) which is the oldest described endemic species of the country (**Figs. 1a, 1b**); however, most of these publications are compilations. In contrast, *Lonchorhina mankomara* and *V. sinchi* (Figs. 1c, 1d) are only documented in two or one publication (the original description), respectively, that together with *A. carishina* (three publications) are the endemic species of Colombia described in the last decade. The localities of each species, related in the content about distributions, are indicated with numbers (**Fig. 2**).

Family Emballonuridae

Saccopteryx antioquensis Muñoz & Cuartas, 2001 (Fig. 3).

State of knowledge:

In addition to the original description (Muñoz & Cuartas, 2001), the species has been included in seven publications (Muñoz Arango, 2001; Cuartas-Calle & Muñoz-Arango, 2003; Simmons, 2005; Hood & Gardner, 2008; Solari *et al*., 2013; Mantilla-Meluk *et al*., 2014a; Solari, 2016a). The species description includes also limited information on ecology and natural history

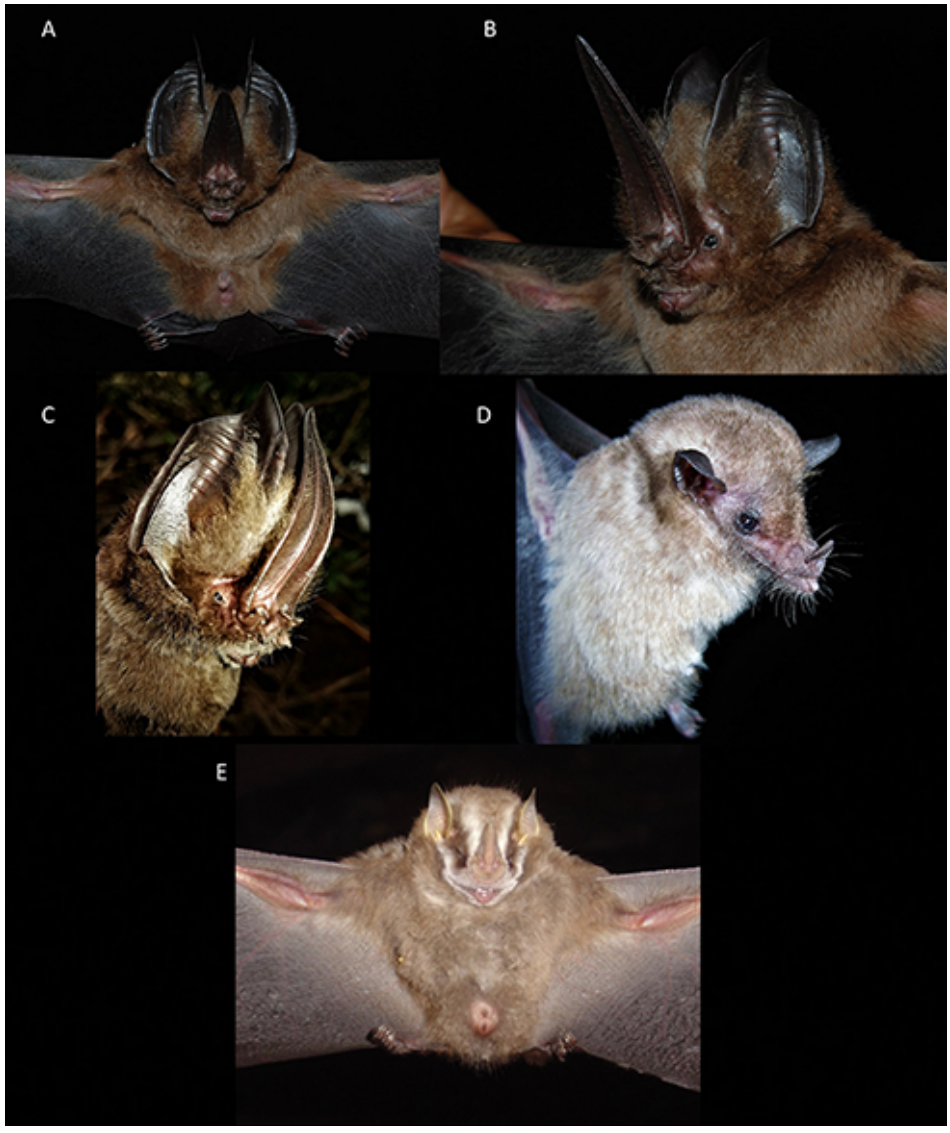

Figure 1. a-b. Marinkelle's sword-nosed bat (*Lonchorhina marinkellei*) from Department of Guaviare, **c.** *Lonchorhina mankomara* from Department of Caquetá, **d**. *Anoura carishina* from Department of Quindío, **e**. Quechuan yellow-eared bat (*Vampyressa sinchi*) from Department of Cauca (paratype, MHNUC 1514).

associated with the taxonomic and distributional descriptions. Five of these publications (Cuartas-Calle & Muñoz-Arango, 2003; Simmons, 2005; Hood & Gardner, 2008; Mantilla-Meluk *et al*., 2014a; Solari, 2016a) are generalities that are mostly based on the original description (Muñoz & Cuartas, 2001). Only one contribution deals with taxonomy (Muñoz Arango, 2001), two with threats/conservation (Simmons, 2005; Solari, 2016a), whereas three additional contributions included additional aspects of biogeography, distribution and records (Muñoz Arango, 2001; Cuartas-Calle & Muñoz-Arango, 2003; Mantilla-Meluk *et al*., 2014a).

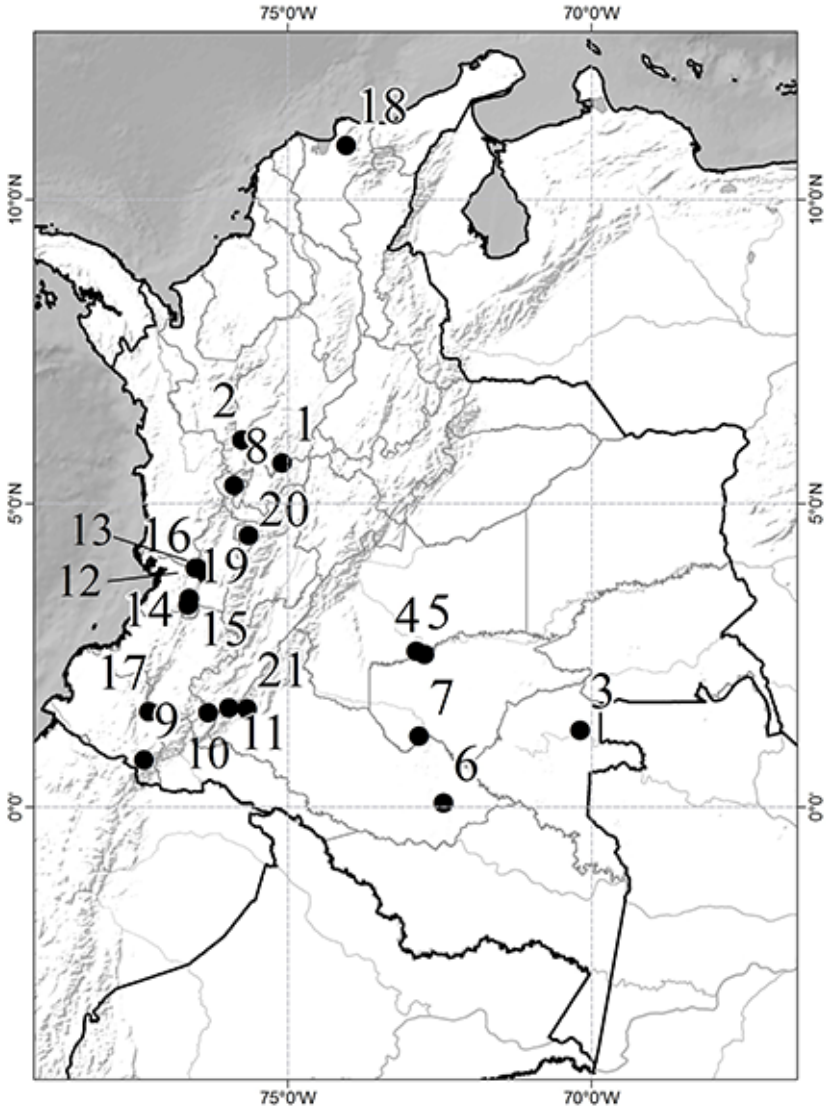

Figure 2. Distribution of the endemic bats of Colombia. Numbers represent localities as follows *Saccopteryx antioquensis* (1, 2), *Lonchorhina marinkellei* (3-5), *Lonchorhina mankomara* (6,7), *Sturnira mistratensis* (8), *Vampyressa sinchi* (9-11), *Anoura cadenai* (12-16), *Anoura carishina* (17-20) and *Carollia monohernandezi* (21).

Distribution

It is only known from two localities; the first is the inter-Andean part of the nor thern section of the Central Cordillera in the Department of Antioquia, Sonsón municipality, vereda La Soledad, ca. 15 km east of the municipality (5°40' N; 75°05' W, 1200 m; locality 1 in Fig. 2; CTUA 617 [MUA 11011]), and San Luis, vereda Las Confusas, quebrada La Cristalina (6°03' N; 75°45' W, 650 m; locality 2 in Fig. 2; CTUA without number [MUA 11012]). No additional records have been provided since its description.

Conservation

S. antioquensis is currently listed as Endangered by the International Union for Conservation of Nature - IUCN (Solari, 2016a), because it is only known from two localities, the extent of occurrence is less than 5 000 km^2 and its area of occupancy (AOO) is estimated to be 8 km^2, and there is no information on aspects of the biology of this species.

Comments

S. antioquensis is morphologically closer to *S. gymnura*. The skull of the holotype (CTUA 617) is shown in Fig. 1. The morphological traits forearm length (36 mm), zygomatic arch width (8 mm), and absence of dorsal lines can be used to separate this taxon from congenerics, but the morphology of this taxon is poorly known. Molecular information is needed to corroborate whether this taxon is a valid species because it is the only species of the genus lackingof phylogenetic analyses (Lim, 2010). The paratype was not found (DMM) in 2016 at CTUA and it is probably lost.

Family Phyllostomidae

Lonchorhina marinkellei Hernández-Camacho & Cadena-G., 1978.

State of knowledge: It is the endemic bat species that has been included in more publications (Marinkelle, 1976; Handley & Ochoa G., 1997; Montenegro & Romero-Ruiz, 1999; Muñoz Arango, 2001; Simmons, 2005; Cadena & Muñoz-Saba, 2007; Williams & Genoways, 2008; Muñoz & Mantilla, 2008; Mantilla-Meluk *et al*., 2009; Ramírez-Chaves, 2011; Solari *et al*., 2013; Solari, 2016b; Mantilla-Meluk & Montenegro, 2016; Suárez-Castro *et al*., 2017), for a total of 15 including the original description (Hernández-Camacho & Cadena-G., 1978). The species description presents limited information on ecology and natural history (diet and distribution) associated with the taxonomic and distributional descriptions. Four of these publications are about anatomy and morphology (Hernández-Camacho & Cadena-G., 1978; Handley & Ochoa G., 1997; Williams & Genoways, 2008; Mantilla-Meluk & Montenegro, 2016), seven on taxonomy and systematics (Hernández-Camacho & Cadena-G., 1978; Handley & Ochoa G., 1997; Cadena & Muñoz-Saba, 2007; Williams & Genoways, 2008; Ramírez-Chaves, 2011; Mantilla-Meluk & Montenegro, 2016; Suárez-Castro *et al*., 2017), eight on biogeography, distribution and records (Hernández-Camacho & Cadena-G., 1978; Handley & Ochoa G., 1997; Montenegro & Romero-Ruiz, 1999; Williams & Genoways, 2008; Mantilla-Meluk *et al*., 2009; Solari *et al*., 2013; Mantilla-Meluk & Montenegro, 2016; Delgadillo-Ordoñez *et al*., 2018), eight on generalities (Muñoz Arango, 2001; Simmons, 2005; Cadena & Muñoz-Saba, 2007; Muñoz & Mantilla, 2008; Williams & Genoways, 2008;

Figure 3. Details of the skull of the holotype (CTUA 617) of the Antioquian sac-winged bat (*Saccopteryx antioquensis*). Scale bar: 10 mm.

Mantilla-Meluk *et al*., 2009; Solari, 2016b; Suárez-Castro *et al*., 2017; Delgadillo-Ordoñez *et al*., 2018), and two on threats/conservation (Solari, 2016b; Suárez-Castro *et al*., 2017). A comprehensive summary of all the available information on the species was recently published (Suárez-Castro *et al*., 2017).

Distribution

Until 2016, it was only known from the type locality in Mitú, comunidad Urania (Durania), Department of Vaupés (01°16' N; 70°11' W, 180 m; locality 3 in in Fig. 2; Mantilla-Meluk & Montenegro 2016; Suárez-Castro et al., 2017) and one locality in the Department of Caquetá (see comments). Specimens from Caquetá were recently described as a new species (*Lonchorhina mankomara* Mantilla-Meluk & Montenegro, 2016). *L. marinkellei* has been recently found (June 2016) in the Department of Guaviare, with two specimens collected: ICN 22472 from Serranía de La Lindosa, cascada Las Delicias, vereda El Retiro, San José del Guaviare municipality (02°30' 47.2" N; 72°44' 42.0" W, 300 m, locality 4 in Fig. 2); and ICN 23138 from Raudal de Angosturas II, vereda El Raudal del Guayabero, San José del Guaviare (02°34' 02.6" N; 72°52' 58.9" W, 300 m, locality 5 in Fig. 2; Morales-Martínez and López-Arévalo, 2018).

Conservation

L. marinkellei is currently listed as Vulnerable (VU) by the IUCN (Solari, 2016b) but includes records from Caquetá identified as *L. mankomara* by Mantilla-Meluk & Montenegro (2016). A re-evaluation of its area of occupancy (AOO) is necessary considering new localities.

Comments

Montenegro & Romero-Ruiz (1999) listed five specimens captured at Serranía de Chiribiquete, Department of Caquetá as *L. marinkellei*. Later, four of these specimens (ICN 14584-87) were re-identified as *L. mankomara* by Mantilla-Meluk & Montenegro (2016). The identity of the fifth specimen remains uncertain. The skull of the holotype and additional specimens from the type locality (Ramírez-Chaves, 2011) have been illustrated in recent publications (Mantilla-Meluk & Montenegro, 2016; Suárez-Castro *et al*., 2017).

Lonchorhina mankomara Mantilla-Meluk & Montenegro, 2016

State of knowledge

It is only known from the original description (Mantilla-Meluk & Montenegro, 2016), and two additional paper where recent records obtained

27 years after the collection of the specimens used as the type series are presented (Mantilla-Meluk *et al*., 2018). The species description presents limited information on ecology and natural history associated with the systematics and distributional description.

Distribution

It is only known from two localities: Río Mesay, Puerto Abeja (Tepui), Southeastern portion of Serranía de Chiribiquete, The National Park Chiribiquete (PNN Chiribiquete, 0°04' N; 72°26' W, 340 m; type locality; locality 6 in Fig. 2; Mantilla-Meluk & Montenegro 2016), and the Serranía de Chiribiquete, Department of Caquetá (locality 7 in Fig. 2; Mantilla-Meluk *et al*. 2018).

Conservation

There are not current assessments of its threaten category. Due the limited extend of occurrence, and the extreme transformation of Colombian Guianan forest, the species might be better placed in the Endangered category. Contradictory, Mantilla-Meluk *et al*. (2018) mentioned that the species described in 2016 is included as Least Concern (LC) on the Red Book of Mammals of Colombia that was published in 2006 (Rodríguez-Mahecha *et al*., 2006). Its area of occupancy (AOO) estimated to be 8 km^2.

Comments

Genetic analyses are needed to clarify whether the morphological differences with *L. marinkellei* are not due to clinal variation. Up to date, all documented specimens assigned to *L. mankomara* from the new locations presented herein fit within measurements in the description of the species. Based on captures, the species is more active late in the night after 21:00 h and early in the morning between 4:00 and 5:00 h. Many individuals were captured at the same time and mist-net, suggesting a gregarious foraging behavior, with larger numbers of females. All captures of large Lochorhina (*L. marinkellei* and *L. mankomara*) both at the PNN Chiribiquete (central and northern portions) and Serrania de La Lindosa, in the departments of Caquetá and Guaviare, Colombia, were registered at rocky formations near or on water courses. The only material recovered in the feces of the species corresponded to a soft and sometimes liquid mass of an apparent animal origin. Four specimens on which the species description was based on were previously reported as *L. marinkellei* by Montenegro & Romero-Ruiz (1999).

Sturnira mistratensis Contreras Vega & Cadena, 2000 (Fig. 4).

State of knowledge

It is only known from the holotype and the original description. The species description presents limited information on morphology and the taxonomic and distributional descriptions (Contreras Vega & Cadena, 2000). Three additional papers and one congress abstract provided information on its taxonomy (Gardner, 2008b; Solari *et al*., 2013; Castaño *et al*., 2017; Torres-Arboleda *et al*., 2019), and two on threats/conservation (Simmons, 2005; Mantilla-Meluk, 2015).

Distribution

It is only known from the type locality in corregimiento de Puerto de Oro (05°18' N; 75°53' W, 980 m; locality 8 in Fig. 2; Contreras Vega & Cadena, 2000), Mistrató, Department of Risaralda (Simmons, 2005; Gardner, 2008b; Solari *et al*., 2013).

Conservation

The species has been listed as Data Deficient by the IUCN (Mantilla-Meluk, 2015). It was not included in the in IUCN/SSC Action Plan - 2001 (Simmons, 2005). Its area of occupancy (AOO) is estimated to be 4 km^2.

Comments

This taxon probably represents a junior synonym of *S. parvidens* (Solari *et al*., 2013; Castaño *et al*., 2017). No additional records apart of the holotype, collected in August 26, 1991 are known and the molar differences in the lower molars (presence of an entoconid plus a paraconulid in the lower molars) are perhaps an abnormality (Solari *et al*., 2013; Castaño *et al*., 2017). Genetic analyses using crusties from the holotype might clarify the controversial specific status of this taxon.

Vampyressa sinchi Tavares, Gardner, Ramírez-Chaves & Velazco, 2014

State of knowledge

It is only known from the original description (Tavares *et al*., 2014). The species description presents limited information on ecology and natural history (diet and distribution) and threats /conservation, associated with the taxonomic and distributional descriptions.

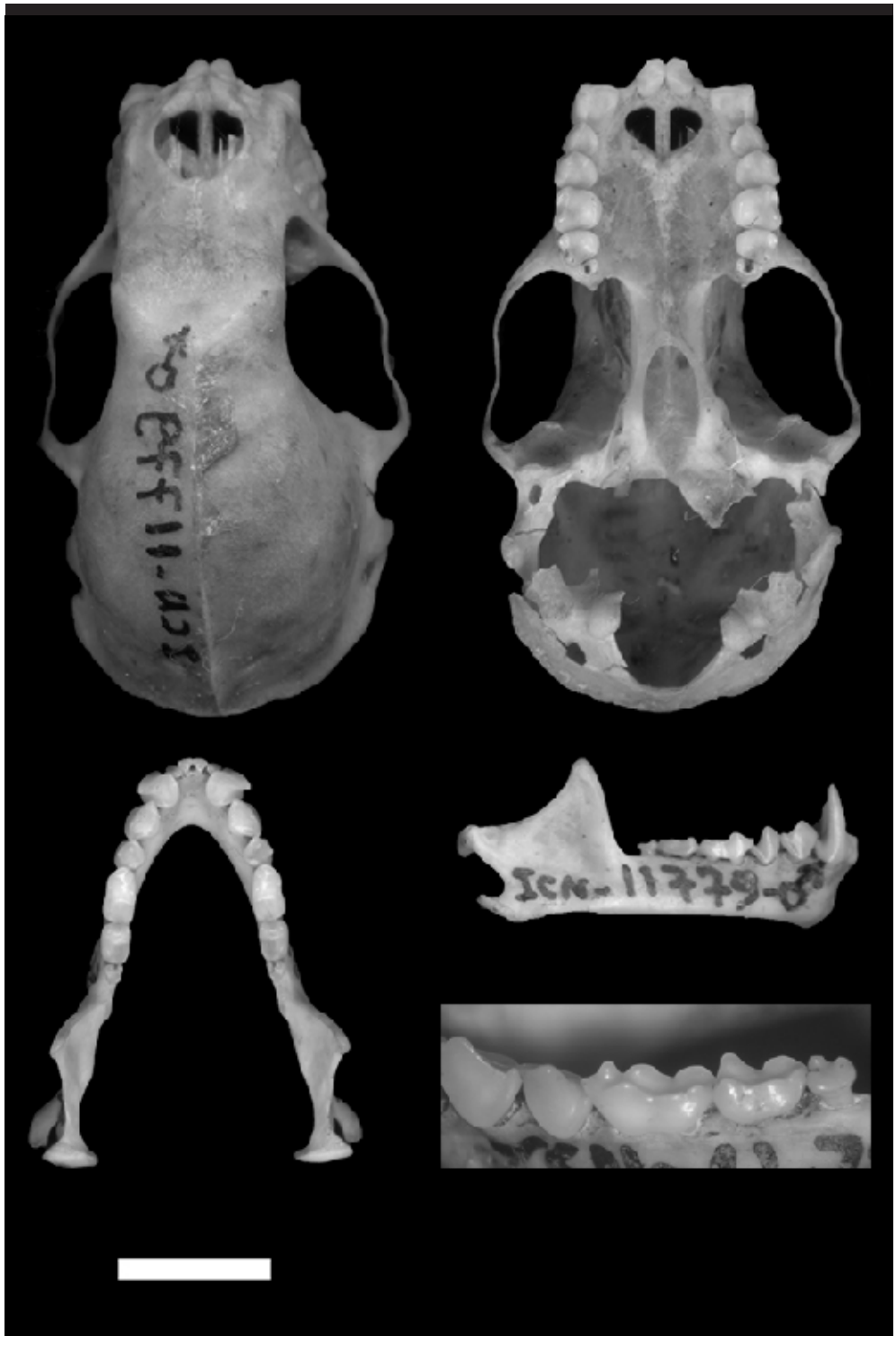

Figure 4. Details of the skull and the paraconulid present on m1 and m2, of the holotype (ICN 11779) of the Mistrató yellow-shouldered (*Sturnira mistratensis*). Scale bar: 10 mm.

Distribution

It was described based on three specimens from the eastern slopes of the Eastern Cordillera in the departments of Cauca, Huila and Nariño, southwestern Colombia (Tavares *et al*., 2014). Three localities have been reported: Llorente, Córdoba municipality, Department of Nariño (0°46' 40" N; 77°21' 50" W, 1700 m; locality 9 in Fig. 2); San Juan de Villalobos, vereda La Esmeralda, Santa Rosa, Department of Cauca (1°33' 18" N; 76°18' 19" W, 1620 m; locality 10 in Fig. 2); and Parque Nacional Natural Cueva de los Guácharos, Acevedo, Department of Huila (1°38' N; 75°58' W, 1900 m; locality 11 in Fig. 2).

Conservation

There are not current assessments of its threaten category. Due the limited extend of occurrence, and its rarity (even rarer than *V. melissa* which is considered as VU by the IUCN; Ramírez-Chaves *et al*., 2015), this species might be considered in the Endangered category. Its area of occupancy (AOO) is estimated to be 16 km^2.

Comments

The species was separated from *V. melissa* by its larger size. However, genetic analyses are needed to corroborate that size differences are associated with linage diversification. The holotype was collected on May 10, 1971. The most recent record from department of Cauca was collected on May 5, 2005 (Fig. 1d and **Fig. 5**; Tavares *et al*., 2014). One specimen on which the description was based (paratype IAvH 2282) collected in August 3, 1976, was previously reported as *V. melissa* (Lemke *et al*., 1982).

Anoura cadenai Mantilla-Meluk & Baker, 2006.

State of knowledge

The species has been included in eight publications (Griffiths & Gardner, 2008; Jarrín-V. & Kunz, 2008; Moreno Mosquera, 2011; Ramírez-Chaves, 2011; Solari *et al*., 2013; Mantilla-Meluk *et al*., 2014b; Solari, 2017) including the original description (Mantilla-Meluk & Baker, 2006). Four of these publications include comments on taxonomy and systematics (Griffiths & Gardner, 2008; Jarrín-V. & Kunz, 2008; Ramírez-Chaves, 2011; Mantilla-Meluk *et al*., 2014b). Only three documents include scarce information on its ecology and natural history (habitat use: Moreno Mosquera, 2011; reproduction: Griffiths & Gardner, 2008) and on threats/conservation (Solari, 2017).

Figure 5. Details of the skull of the paratype (MHNUC 1514) of the Quechuan yellow-eared bat (*Vampyressa sinchi*). Scale bar: 10 mm.

Distribution

It is known from the Western Cordillera of Colombia, in the Department of Valle del Cauca (elevational range 800-1600 m; Mantilla-Meluk & Baker, 2006) as follows: "between the municipalities of Calima and Restrepo near the Rio Bravo at 1000 m elevation" (3°56' 03" N; 76°29' 18" W, 100 m; locality 12

in Fig. 2); Calima (3°56' 3" N; 76°29' 18" W, 1400 m; locality 13 in Fig. 2); Pichindé (3°26' N; 76 °37' W, 1000 m; locality 14 in Fig. 2); 2 km S of Pance (3°19' 30" N; 76°38' 20" W, 1400 m; locality 15 in Fig. 2), and Yotoco (Yotoco municipality; 3°52' 1" N; 76°22' 59" W, 954 m; locality 16 in Fig. 2).

Conservation

The species has been listed as Data Deficient by the IUCN (Solari, 2017). Its area of occupancy (AOO) is estimated to be 20 km^2.

Comments

The catalogue numbers of the paratypes as listed in the description (USNM [United States National Museum - National Museum of Natural History; Smithsonian Institution; Washington, DC] 48369, 48368, 48366, 48367 and 48371; (Mantilla-Meluk & Baker, 2006), have in fact the catalogue numbers USNM 483369, 483368, 483366, 483367 and 483371). In addition, the paratype USNM 486670, needs to be verified because the number appears at the USNM mammal database as belonging to a rodent (*Zapus princeps*) collected on 15 July 1971 by Gaffney, P. M. In another case, the paratype USNM 123442 belongs to a specimen collected by Robert, A. in Brazil, Sao Paulo, Pequete.

Anoura carishina Mantilla-Meluk & Baker, 2010 (Suppl.2)

State of knowledge

The species has been included in three papers apart of the original description that mentioned comments on its taxonomy (Ramírez-Chaves, 2011), and morphology (Mantilla-Meluk *et al*., 2014b).

Distribution

It is known from the Andean region and the Sierra Nevada de Santa Marta (elevational range 1200-1465 m; Mantilla-Meluk & Baker, 2010): Taminango, Department of Nariño (1°34' 23" N; 77°16' 59" W, 600 m; locality 17 in Fig. 2); Pedro de La Sierra, Finca Tierra Grata, Department of Magdalena (10°54' 06" N; 74°02' 00" W, 1320 m; locality 18 in Fig. 2), Pance, Department of Valle del Cauca (3°19' 42 "N; 76°38' 19" W, 1200 m; locality 19 in Fig. 2), and vereda La Virginia, Calarcá, Department of Quindío (4°29' 24 " N; 75°38' 33" W, 1582 m; locality 20 in Fig. 2). The species has been recently found in the Department of Cauca (Ascuntar-Osnas *et al*., 2020; not mapped).

Ecology

Colonies have been reported inhabiting cave systems and abandoned tunnels at the Department of Quindío, Central Andes of Colombia. Havens of *A. carishina* are characterized by a constant temperature varying between 12.4 °C and 12.7 °C. The number of individuals in the colonies varies according to the reproductive season. AFV-A and HM-M have documented up to 400 individuals at the artificial tunnel "La Línea" in Calarcá, Quindio, grouped inclusters of 18 bats in average. There is spatial sexual segregation inside the haven, with females established at the microclimatic more stable areas, and males located, preferentially, at the entrance of the caves and tunnels with an intermediate zone of sexually mixed individuals, used for mating. At the end of the mating season, males abandon the haven. *A. carishina* has a monoestral reproductive cycle, coincident with the rainy season at the Central Andes in Colombia. The mating season starts in Augusts, ending in late September, period in which males reported the maximum testicular size (> 5.3 mm). The first pregnancies were documented at mid-December with lactating females between January and March.

Conservation

The species has not been included in any assessment. Its area of occupancy (AOO) is estimated to be 16 km^2. The species has been recently reported at the Department of Quindio, vereda La Virginia, Calarcá.

Comments

Considering that *A. carishina* was separated from the *A. geoffroyi* complex, genetic analysis are needed to provide further evidence of the species validity.

Carollia monohernandezi Muñoz, Cuartas-Calle & González, 2004.

State of knowledge

Apart of the original description (Muñoz *et al*., 2004), it appears in four papers on its biogeography, distribution and records, and generalities (McLellan & Koopman, 2008; Mantilla-Meluk *et al*., 2009; Zurc & Velazco, 2010; Solari *et al*., 2013).

Distribution

It is currently restricted to the holotype that was collected in November 23, 1993 at vereda Villaraz, Florencia municipality, Department of Caquetá (0°37'N; 75°40' W, 1200 m; Muñoz *et al*., 2004; Zurc & Velazco, 2010; locality 21 in Fig. 2).

Conservation

The species has not been included in any assessment. Its area of occupancy (AOO) is estimated to be 4 km^2.

Comments

The type series (n = 22) of *C. monohernandezi* was re-identified as *C. brevicauda* (n = 5) and *C. perspicillata* (n = 11); whereas, the holotype (MUA 11014, currently CTUA 119; **Fig. 6**) was validated as a different

Figure 6. Details of the skull of the holotype (CTUA 119) of the Mono Hernández's short-tailed bat (*Carollia monohernandezi*). Scale bar: 5 mm.

taxon based on the size and cranio-dental traits (Zurc & Velazco, 2010). The remaining specimens were not found (Zurc & Velazco, 2010). Nevertheless, genetic analyses of this specimen (CTUA 119), are needed to corroborate this hypothesis.

Distribution

The distribution of the endemic bats includes 10 departments from which departments of Cauca, Guaviare, Nariño and Valle del Cauca have the greater number of endemic bats (2 species; **Fig. 7a**). At municipal level, the endemic bats are distributed in zones from 16 municipalities. Cali (2 species) supports the greater numbers of endemic bats (Fig. 7b). The endemic bats inhabit nine Colombian ecosystems (**Table 1**), but the most representative ecosystem was the Cauca Valley

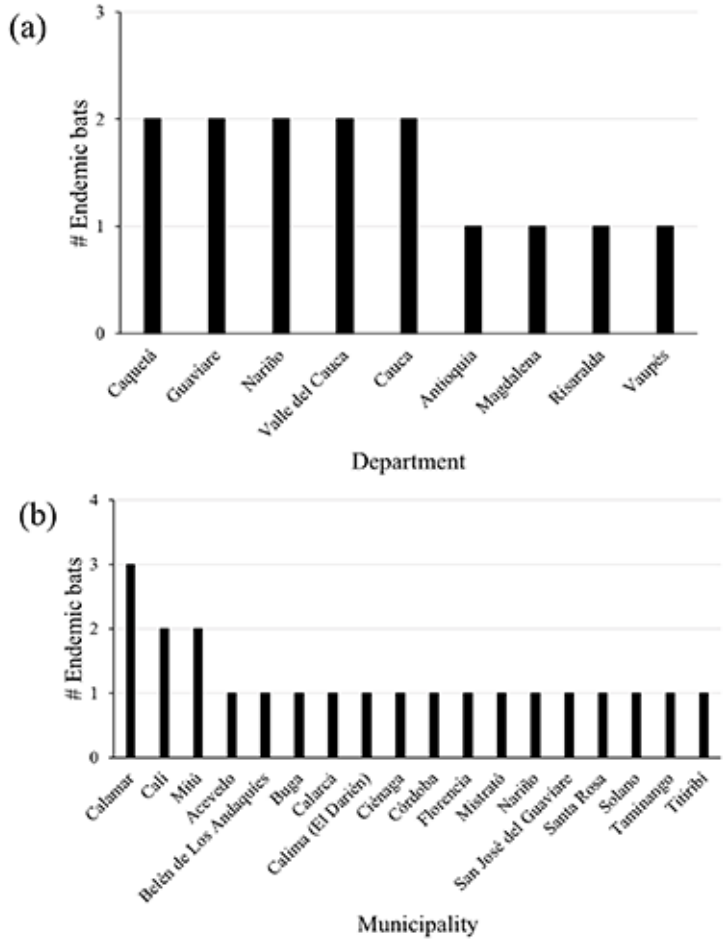

Figure 7. Number of endemic bats grouped by (**a**) departments and (**b**) municipalities of Colombia.

Table 1. Representativeness of the endemic bats in the Colombian ecosystems.

Type of ecosystem	*A. cadenai*	*A. carishina*	*C. monohernandezi*	*L. mankomara*	*L. marinkellei*	*S. antioquensis*	*S. mistratensis*	*V. sinchi*	Number of endemic species
Caquetá moist forests				X	X				2
Cauca Valley dry forests	X								1
Cauca Valley montane forests	X	X				X	X		4
Cordillera Oriental montane forests			X						1
Eastern Cordillera real montane forests								X	1
Magdalena Valley montane forests						X		X	2
Northwestern Andean montane forests	X	X							2
Purus varzeá				X	X				2
Santa Marta montane forests		X							1
Number of ecosystem	3	3	1	2	2	2	1	2	

montane forests with four species. One area of endemism composed by two ecosystems (Caquetá moist forests and Purus varzeá) and supported by *L. mankomara* and *L. marinkellei* was identified in Colombia (**Fig. 8**). The potential distribution of *A. cadenai* showed higher values of suitability in the departments of Cauca, Huila, Risaralda Tolima and Caldas, on the Central Cordillera (**Fig. 9**, Suppl. 1). The potential distribution of *A. carishina* extends throughout the three Andean mountains (Western, Central and Eastern mountains), from north of Ecuador to Antioquia and Norte de Santander in Colombia (**Fig. 10**, Suppl. 1). The potential distribution of *L. marinkellei* included zones on the eastern Llanos Basin of Colombia and Amazonia in the departments of Arauca, Casanare, Guaviare, Guainía, Meta, Vaupes, and Vichada (**Fig. 11**, **Suppl. 1**). *V. sinchi* is potentially distributed on the Western Cordillera, and it includes zones from the north of Ecuador and South of Colombia (Nariño) to Caldas and Antioquia (**Fig. 12**, Suppl. 1).

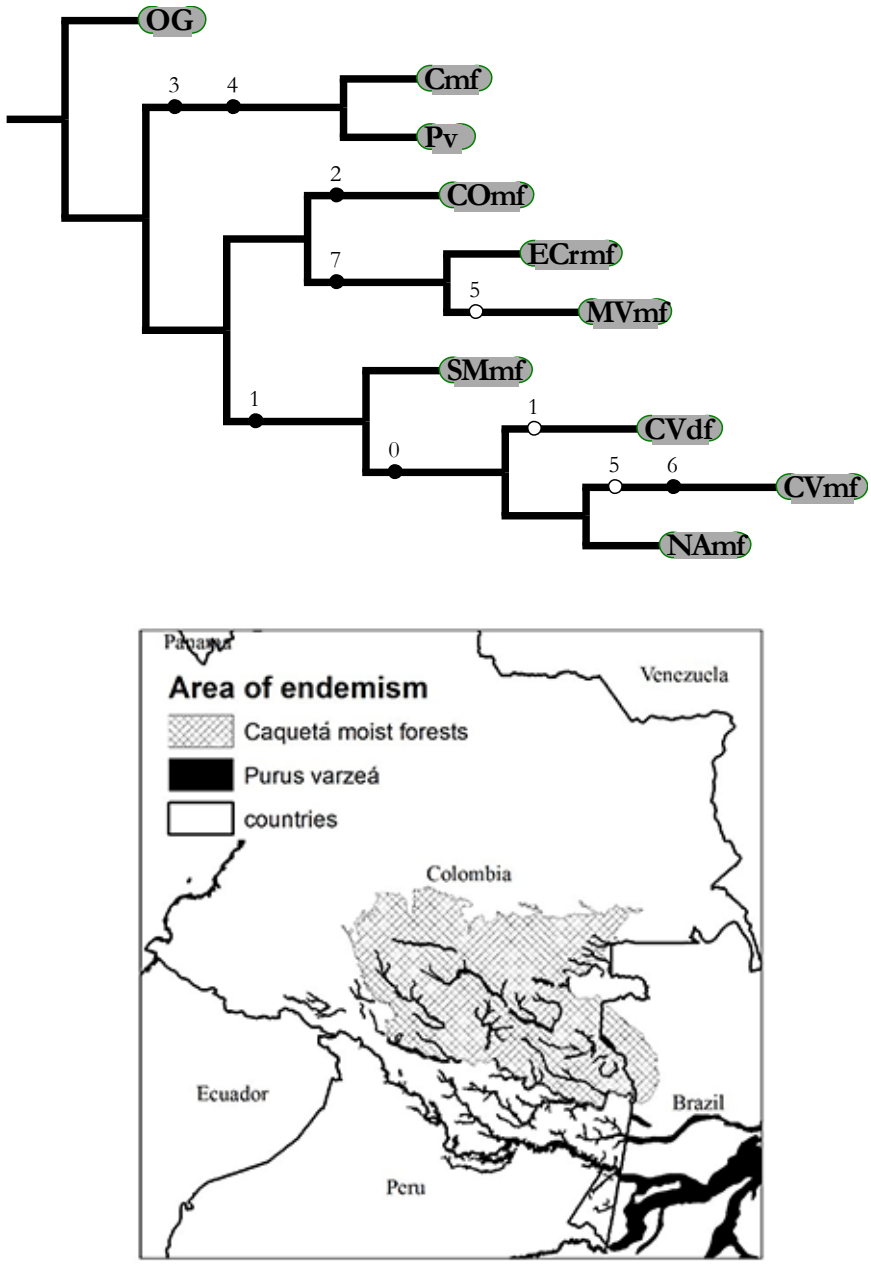

Figure 8. Cladogram obtained from the Parsimony Analysis of Endemism (PAE) (tree length = 10, CI = 0.8, RI = 0.7). Numbers represent endemic bats, 0) *A. cadenai*, **1**) *A. carishina*, **2**) *C. monohernandezi*, **3**) *L. mankomara*, **4**) *L. marinkellei*, **5**) *S. antioquensis*, **6**) *S. mistratensis*, and **7**) *V. sinchi*. OG=outgroup, Cmf= Caquetá moist forests, CVdf= Cauca Valley dry forests, CVmf= Cauca Valley montane forests, COmf= Cordillera Oriental montane forests, ECrmf= Eastern Cordillera real montane forests, MVmf= Magdalena Valley montane forests, NAmf= Northwestern Andean montane forests, Pv= Purus varzeá, and SMmf= Santa Marta montane forests. Black dots are synapomorphies, and white dots are homoplasy. Box and map indicate the area of endemism identified using endemic bats distributions, supported by two synapomorphies (*L. mankomara* and *L. marinkellei*).

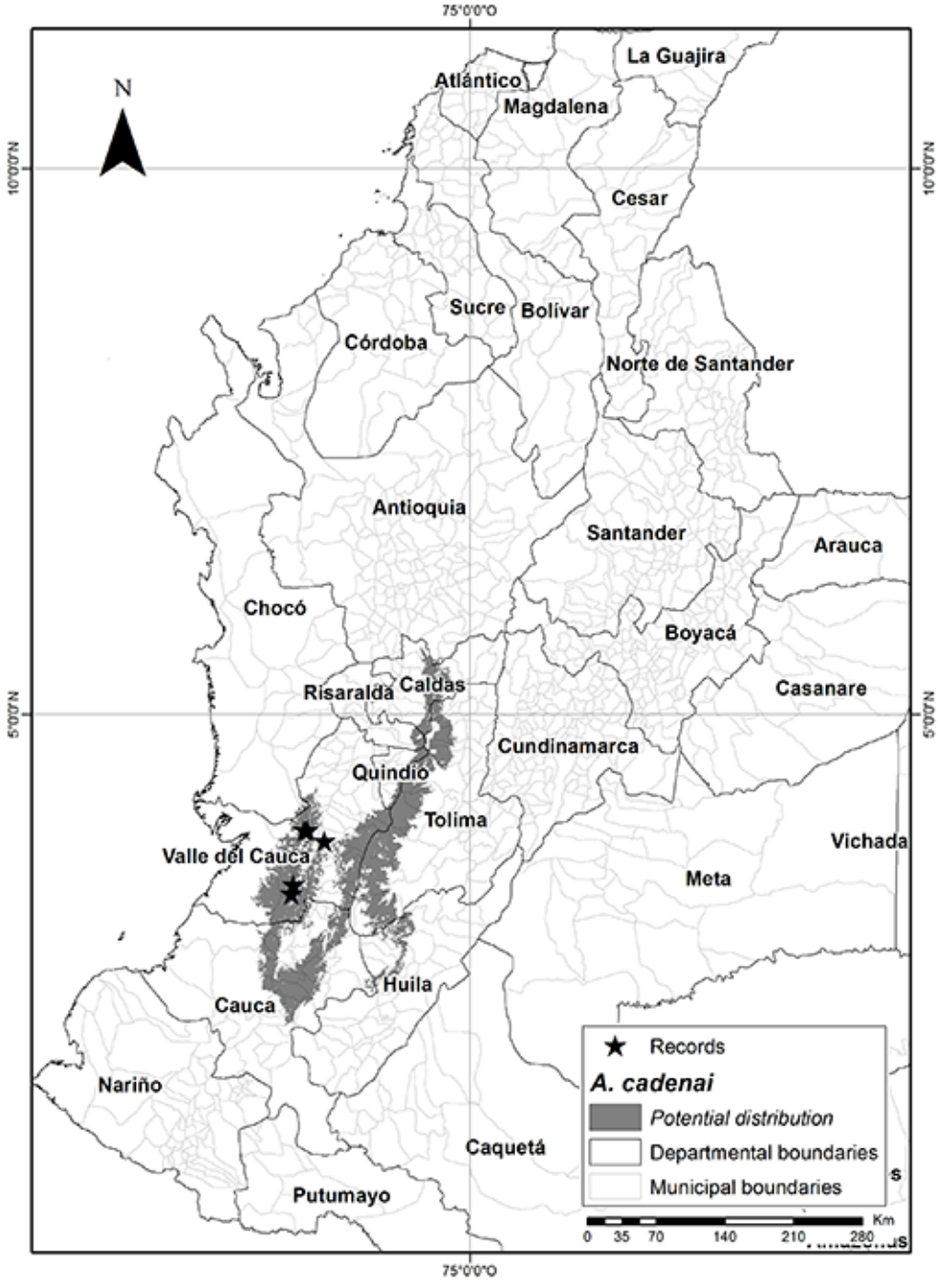

Figure 9. Potential distribution of *A. cadenai*. Lowest presence threshold used 0.66. n - 1 jackknife indicated significative model (Successes 2; p-value 0.0001; AUC 0.99).

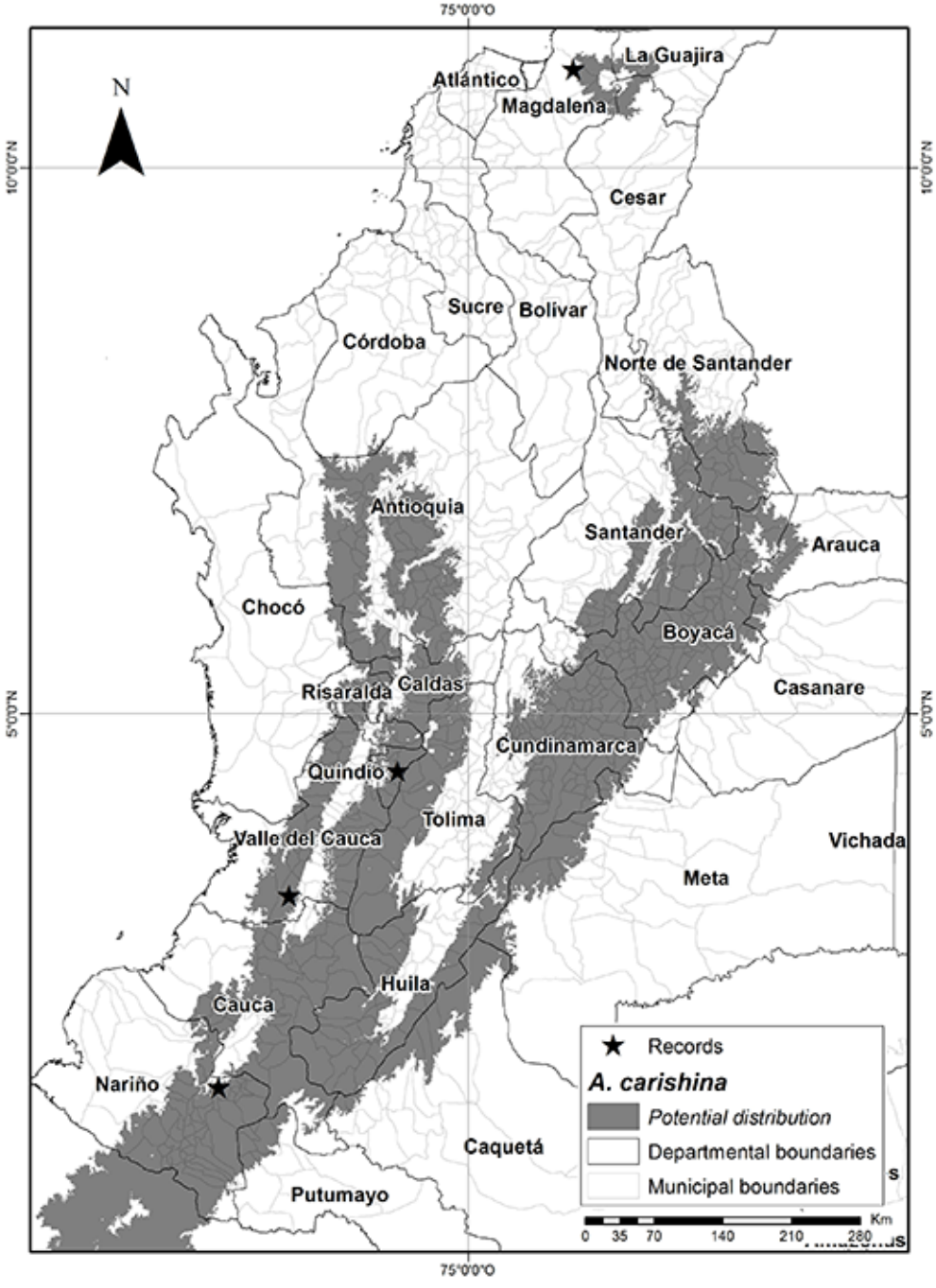

Figure 10. Potential distribution of *A. carishina*. Lowest presence threshold used 0.57. n - 1 jackknife indicated no significative model (Successes 1; p-value 0.1; AUC 0.95).

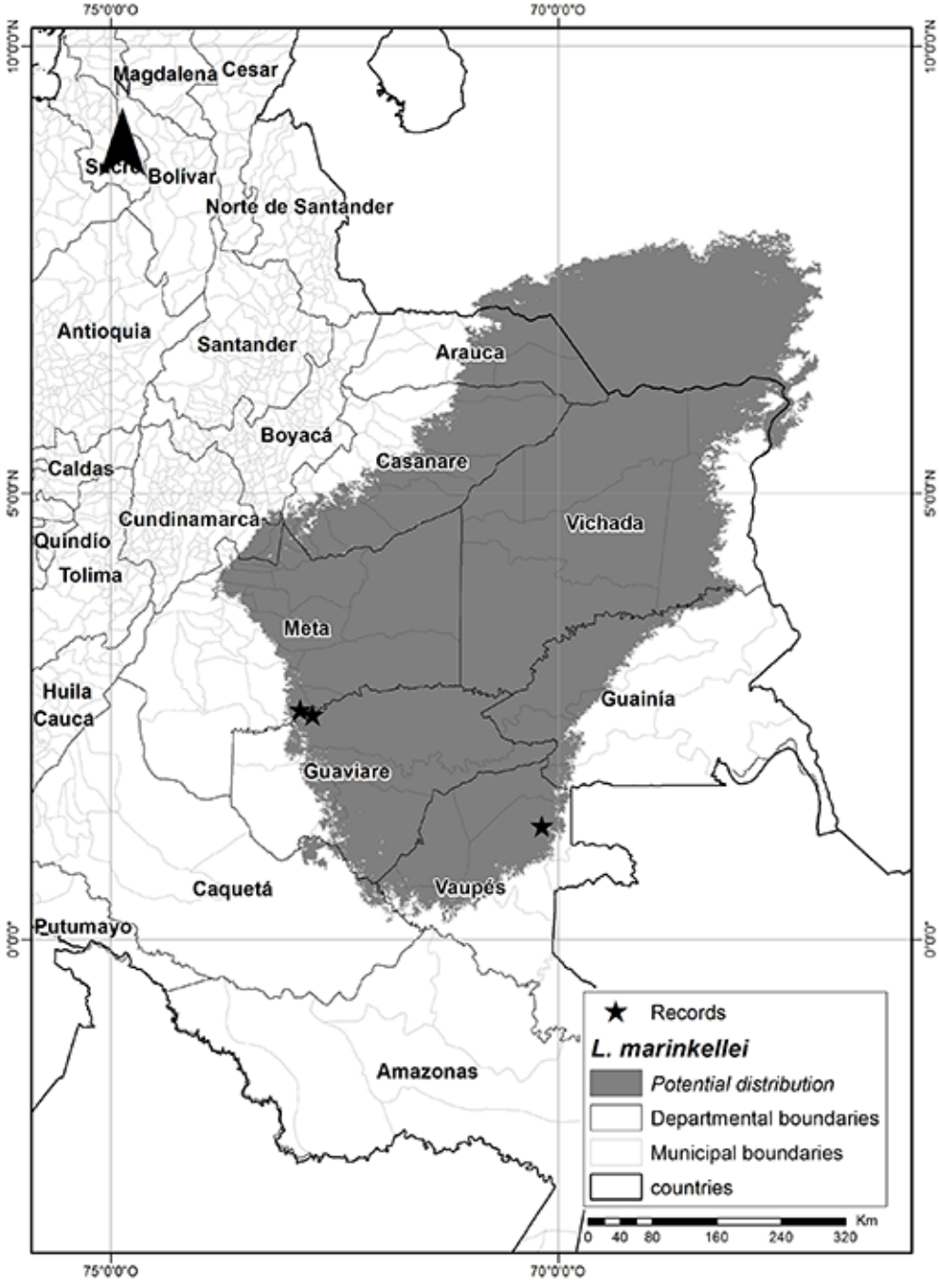

Figure 11. Potential distribution of *L. marinkellei*. Lowest presence threshold used 0.54. n - 1 jackknife indicated significative model (Successes 2; p-value 0.03; AUC 0.95).

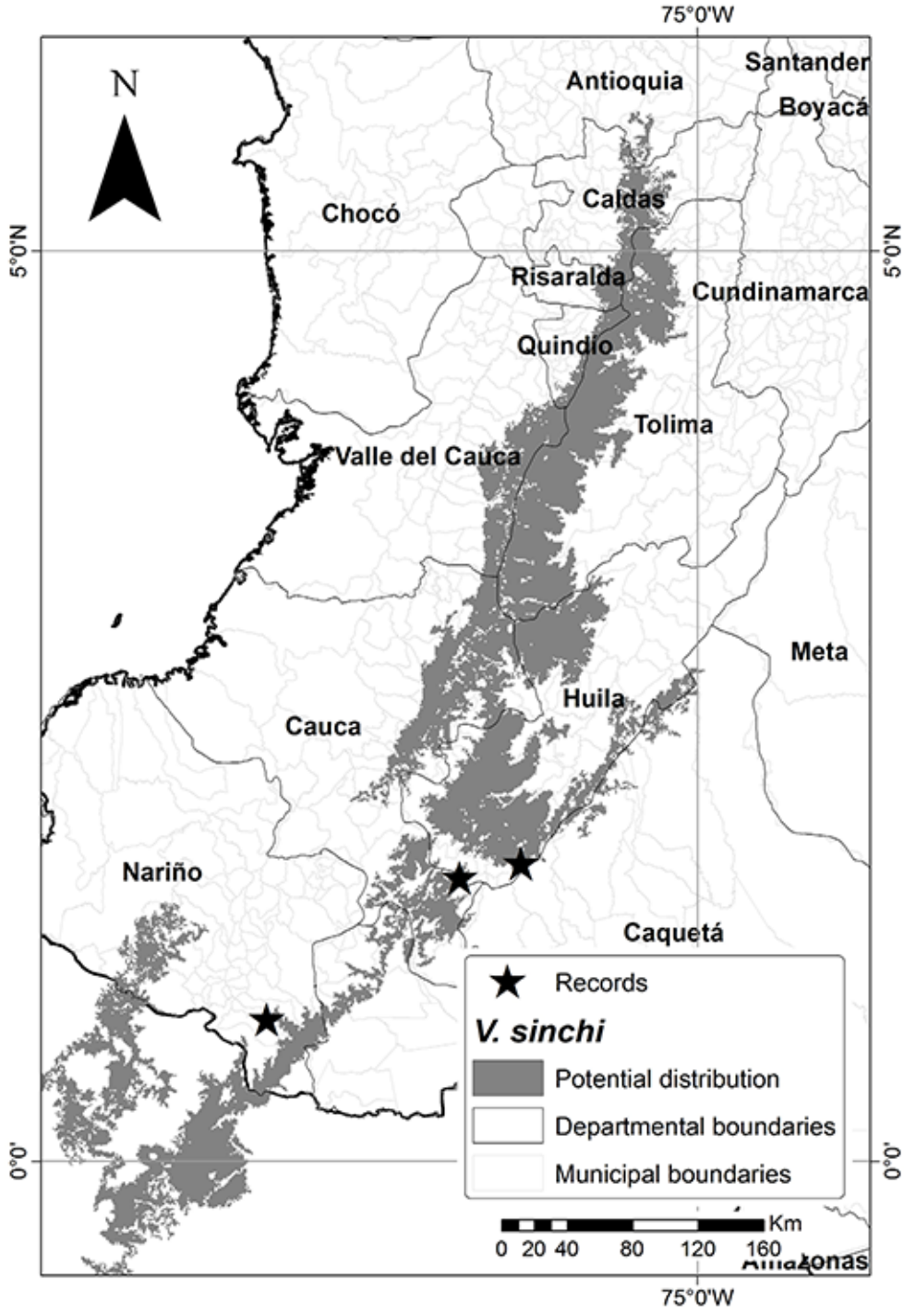

Figure 12. Potential distribution of *V. sinchi*. Lowest presence threshold used 0.65. n - 1 jackknife indicated significative model (Successes 1; p-value 0.03; AUC 0.99).

Discussion

The definition of endemic bat species for Colombia has been a topic that was little explored in the last 20 years. For 2000 no bat species were listed as endemic of Colombia (Alberico *et al*., 2000), however, for 2013 the number of endemic species for the country was seven (Solari *et al*., 2013), but of these *Hsunycteris cadenai* (Phyllostomidae) was reported in Ecuador (Tirira, 2012). The two-additional endemic species, in comparison with the information of Solari *et al*. (2013) are *V. sinchi* and *L. mankomara* that were described in 2014 and 2018, respectively. It is possible that some of the endemic species of Colombia inhabit in neighboring countries. Considering the potential distributions maps, *A. carishina* and *V. sinchi* are likely distributed in Ecuador. Similarly, *L. marinkellei* could be present in Venezuela; however, some Lonchorhina have very specific habitat requirements that might limit their real distribution (Morales-Martínez & López-Arévalo, 2018). Although, the ecological niche models using small number of samples cause overprediction in the potential distributions or no significative model (v.g. Potential distribution of *A. carishina*; p-value 0.1), the maps of the endemic species are initial hypotheses that provide valuable biogeographical information to identify regions that have similar environmental conditions to where the species currently inhabits (Pearson *et al*., 2007; Proosdij *et al*., 2016), which could be used to select places to search new populations (Pearson *et al*., 2007). The number of endemic species found in Colombia is low; however, this seems to be the general pattern for other South American countries such as Ecuador and Peru (six and seven endemic species respectively; Pacheco *et al*., 2009; Tirira, 2015). Larger countries as Brazil holds 14 endemic bats, mostly phyllostomids (Paglia *et al*., 2012).

Hernández-Camacho *et al*. (1992) proposed 58 centers of endemism in Colombia, based on the identification of restricted range species ($< 50\,000$ km^2). Comparing the known distribution of the endemic bats with the centers of endemism (Hernández-Camacho *et al*., 1992), the endemic bats support nine centers. Under actual knowledge, five endemic bats are restricted to Colombian endemism centers proposed by Hernández-Camacho *et al*. (1992): *S. antioquensis* (Nechi-Nare Center) *L. marinkellei* (Vaupés Center), *L. mankomara* (Chiribiquete Center), *A. cadenai* (Biogeographic Chocó Center), *C. monohernandezi* (Piedemonte de Florencia Center), and two species are reported in two endemic centers *V. sinchi* (Piedemonte de Florencia Center and Cofane Center) and *A. carishina* (Chocó Center and Sierra Nevada de Santa Marta Center). By identifying the coincidence of the distribution bats with endemism centers of Colombia, this study adds eight species of bats to the list of 45 species and subspecies of endemic mammals that support the endemism centers (Hernández-Camacho *et al*., 1992), and also revalidates the importance of bats in the identification of geographic zones. For example, Cauca Valley

montane forests could be a prime ecosystem to analyze the ecology of four endemic bats, whereas departments as Valle del Cauca and Caquetá, and the municipalities of Calamar, Cali or Mitú comprise zones that could be important to develop conservation strategies (i.e., AICOM's: Áreas Importantes para la Conservación de Murciélagos/Important Areas for Bat Conservation, and SICOM's: Sitios Importantes para la Conservación de Murciélagos/Important Sites for Bat Conservation) around the endemic bats.

Parsimony Analysis of Endemicity based on endemic bats resulted in the identification of one area of endemism in the Amazon basin. Although it is comprised of only two species (*L. mankomara* and *L. marinkellei*), the Amazon basin has been identified as an important center of endemism (Kier *et al*., 2009), and it is recognized as an important biogeographic pattern to others biological groups (Costa *et al*., 2000; Noguera-Urbano & Escalante, 2015), due to multiple neotropical evolutionary and geological process that occurred in that area (Hoorn *et al*., 2010). Even though endemic species represent a national natural patrimony that should be priority for research activities and conservation, none of the species evaluated have been deeply studied or included in the national red lists or government resolutions (Rodríguez-Mahecha *et al*., 2006; Ministerio de Ambiente y Desarrollo Sostenible, 2017). It is an urgent activity to clarify the taxonomic status of at least four of these endemic bats of Colombia, thus, the risk of extinction of these lineages could be properly assessed. The inclusion of these endemic species in evolutionary studies is an urgent activity considering that they are missing from phylogenies (Lim, 2007). Further study of this topic should contribute both to increased understanding of the endemic species in Colombia, and to propose strategies and policies of conservation of the endemic species. Finally, endemic species (specialist species) probably are expected to have smaller tolerances to climate change in comparison whit generalist species (Brown, 1995). Therefore, negative factors as climate change (Thuiller *et al*., 2005), and the loss of biological and socioeconomic functions of ecosystems, affect the endemic species too (Pinilla-Buitrago *et al*., 2018); thus, they require to be treated as targets of a global, regional, and national conservation strategies.

Conclusions

Even though the first endemic bat of Colombia was described nearly 30 years ago, little is known on the species under this category. In general, the pattern is the absence of knowledge in all the topics evaluated. However, the distributional information is the most recurrent research topic, but the records for all endemic species come from only 21 localities. Field work to obtain new records of endemic bat species of Colombia is needed, and molecular tools should be used to address controversial issues on taxonomy and systematics. With this novel information, the threaten category for all the endemic species should be re-assessed.

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Conflict of interest

The authors certify that they have no conflict of interest.

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Murciélagos endémicos (Mammalia: Chiroptera) de Colombia: estado del conocimiento, distribución y conservación

Resumen: Colombia, con 209 especies, es uno de los países más ricos en términos de diversidad de murciélagos. Esta alta diversidad comprende nueve familias y 72 géneros. Un total de ocho especies, de las familias Emballonuridae (n = 1) y Phyllostomidae (n = 7) están listadas como endémicas para el país. A pesar de la relevancia de Colombia en cuanto a diversidad de murciélagos, poco se sabe de estas especies endémicas, que son principalmente conocidas por la localidad tipo (n = 4), mientras que para otras (n = 2) su estado taxonómico es incierto. En el presente estudio se ha compilado la información disponible sobre murciélagos endémicos de Colombia, y se proporciona, además, información nueva sobre su distribución y conservación. La especie más incluida en publicaciones, incluyendo su descripción original (n = 15) fue *Lonchorhina marinkellei*. El único patrón de distribución observado para las especies evaluadas fue para *Carollia monohernandezi* y *Vampyressa sinchi*, que podrían tener distribuciones superpuestas en las vertientes orientales de la Cordillera Oriental. La mayoría de especies endémicas están en las regiones andina e interandina del país (n = 6). A nivel nacional, no hay especies endémicas en ninguna categoría de amenazadas; sin embargo, al menos una especie (*Lonchorhina marinkellei*) se considera como Vulnerable (VU) y una (*Saccopteryx antioquensis*), como Amenazada (EN) por la Unión Internacional para la Conservación de la Naturaleza (UICN).

Palabras clave: Andes; Emballonuridae; Phyllostomidae; Sur América; Categoría de Amenazada.

Morcegos endêmicos (Mammalia: Chiroptera) da Colômbia: estado do conhecimento, distribuição e conservação

Resumo: Colômbia, com 209 espécies, é um dos países mais ricos em termos de diversidade de morcegos. Esta alta diversidade compreende nove famílias e 72 gêneros. Um total de oito espécies, das famílias Emballonuridae (n = 1) e Phyllostomidae (n = 7) estão categorizadas como endêmicas para o país. Apesar da relevância da Colômbia no que se refere à diversidade de morcegos, pouco se sabe sobre estas espécies endêmicas, que são conhecidas principalmente pela sua localidade tipo (n = 4), enquanto para outras (n = 2) o seu estado de conhecimento é incerto. No presente estudo, se compilou a informação disponível sobre morcegos endêmicos da Colômbia, e se proporciona, além, nova informação sobre distribuição e conservação. A espécie mais incluída nas publicações, abrangendo sua descrição original (n = 15) foi *Lonchorhina marinkellei*. O único padrão de distribuição enxergado para as espécies avaliadas foi para *Carollia monohernandezi* e *Vampyressa sinchi* que poderiam ter distribuições sobrepostas nas vertentes orientais da Cordilheira Oriental. A maioria de espécies endêmicas se encontram nas regiões andinas e inter-andinas do país (n=6). No nível nacional, não há espécies endêmicas dentro de alguma categoria de ameaça; contudo, ao menos uma espécie (*Lonchorhina marinkellei*) é considerada como Vulnerável (VU) e uma como Em perigo (EN) (*Saccopteryx antioquensis*) pela União Internacional para a Conservação da Natureza (UICN).

Palavras-chave: Andes; Emballonuridae; Phyllostomidae; América do Sul; Categoria de ameaça.

Héctor E. Ramírez-Chaves

Is interested in mammalogy, evolution and conservation. He currently works at the Biological Department of Universidad de Caldas, and is the Vertebrate Curator at the Centro de Museos, Museo de Historia Natural, Universidad de Caldas.

Elkin A. Noguera-Urbano

Is a biogeographer, and his main research interests are in mammalogy, biodiversity, systematics, conservation planning and spatial modelling.

Darwin M. Morales Martínez

Is a mammalogist and his main research interest is taxonomy, ecology, and systematics of Neotropical bats.

Danny Zurc

Is currently a Ph.D. student, with a Master in Biology at the Universidad de Antioquia. She is the Curator of the biological collections of the Museo de Ciencias Naturales de La Salle, Instituto Tecnológico Metropolitano (Medellín-Antioquia). She has published several papers on the taxonomic status and acoustic identification of bat species, appropriation of science knowledge, and software development.

Andrés Felipe Vargas-Arboleda

Is a Biologist interested in Colombian mammals. He has experience working with mammals from the Coffee Axis Region of Colombia.

Hugo Mantilla-Meluk

Is a mammalogist working on evolution, ecology and conservation, focused on Neotropical taxa. He is the founder and former president and vice-president of the Colombian Society of Mammalogists, and current vice-president of the Colombia Association of Zoologist. He is the founder and Curator of the Collection of Mammals of the Universidad del Quindio; and founder and General Director of the Centre for Highland Studies.