

Original Study

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Urban and peri-urban bats (Mammalia: Chiroptera) in Manizales, Colombia: exploring a conservation area in sub-Andean and Andean ecosystems

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Abstract: In Colombia, 217 bat species have been recorded of which at least 22 species occur in Andean and sub-Andean ecosystems. To evaluate the richness of bats in an Andean elevational range at the Municipality of Manizales, Central Andes of Colombia, we performed surveys supplemented with incidental captures from 2018 to 2022 at different urban and peri-urban areas, and reviewed specimens in biological collections. We evaluated the perception and knowledge that local people have about bats using an online survey. We reported 33 species in the study area. Phyllostomidae showed the highest richness (20 species), followed by Vespertilionidae (11 species), and Molossidae (2 species). For the survey, we obtained responses from 219 people who showed a good knowledge about bats and their ecological importance. We did not find significant differences between ages

and levels of schooling in the perception about bats. Our results highlight the relevance of conserving the green areas of Manizales and the need for environmental education programs to reduce possible bat-human conflicts and negative perceptions. Manizales has the potential as an Area of Importance for the Conservation of Bats, due to its high bat richness and that reproduction is occurring within the study area.

Keywords: bat richness; biological collections; Chiroptera; human-wildlife conflicts; Phyllostomidae

1 Introduction

In the Neotropics, bats (Chiroptera) represent the second most diverse mammal orders with approximately 450 species (Díaz et al. 2021). This diversity is inversely associated with elevation, with a marked reduction of species at high elevations (McCain 2007; McNab 1971; Rahbek 1995), where temperature and resources availability may independently or in association with each other influence this decrease in bat richness (Graham 1983).

In Colombia, located in the northern corner of South America, bats represent the most diverse group of mammals with 217 species (Ramírez-Chaves et al. 2020a). Colombia's high diversity is due partly to its geographical location, and the contrasting natural regions found in the country that includes the Amazon, the Caribbean, Orinoco, Pacific and three Cordilleras of the Andean region (Hernández-Camacho et al. 1992). The Andean region of Colombia covers 24.5 % of the country's surface (Etter and Van Wyngaarden 2000), and it is considered a priority conservation area at a global level, due to its biological richness, high level of endemism and the accelerated habitat loss (Armenteras et al. 2003; Myers et al. 2000). Around 60 % of the bat species recorded in Colombia

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inhabit the Andean region (Castaño et al. 2004; Ramírez-Chaves et al. 2021). Nonetheless, the knowledge of these organisms is limited, especially in higher elevation areas (Castaño et al. 2018). Studies carried out in sub-Andean and Andean forests (1600 and 3750 m a.s.l.) of Colombia have listed between six and 22 bat species (Bejarano-Bonilla et al. 2007; Muñoz Arango 1990; Pérez-Torres and Ahumada 2004; Rodríguez-Posada 2010; Roncancio and Estévez 2007), with only three frugivorous species at elevations over 2000 m (Castaño et al. 2018).

In the Department of Caldas, located in the Central Cordillera of Colombia, between 72 and 85 bat species have been reported (Castaño 2012; Ramírez-Chaves et al. 2020b). Manizales, the capital city of Caldas is an important place in the Colombian coffee region. It has optimal conditions for the presence of a high diversity of flora and fauna, thanks to its structural complexity, geological and climatic history, and its tropical position (Rodríguez-Posada 2010). Manizales houses several sub-Andean and Andean forests that help maintain the local diversity (Raigosa Álvarez et al. 2020; Walker 1996). Between 6 and 20 species have been reported for different localities between 1750 and 3500 m in Manizales (Castaño et al. 2003a; Raigosa Álvarez et al. 2020; Rodríguez-Posada 2010; Sánchez et al. 2004). However, the urban or peri-urban bat richness has not been studied, although information on some ecological interactions such as the presence of bat ectoparasites is available (Raigosa Álvarez et al. 2020). The forested areas of Manizales can provide shelter and resources for bat species, and cavities in buildings might be used as well (Everette et al. 2001; Gaisler et al. 1998; Gehrt and Chelsvig 2003; Kurta and Teramino 1992). Since some species tend to establish themselves on the roofs of buildings, this can generate negative public perceptions (Alberico et al. 2005; Hoffmaster et al. 2016; Sampedro-Marín et al. 2008). This, together with speculations about the origin of SARS-CoV-2 put bats into the spotlight of societal attention (Straka and Voigt 2022). Considering that public perception is key for conservation actions and that bats are usually affected by misconceptions, evaluating the public knowledge about bats in Manizales is critical to avoid human–bat conflicts.

Furthermore, bats are one of the mammalian groups in which richness and abundance can be affected due to urbanization (Pierson 1998) by reducing and fragmenting their habitat (Fenton 2003). Manizales has a consolidated network of protected areas known as Ecoparks (Ecoparques in Spanish). These Ecoparks encompass five forest fragments, three of them classified as peri-urban (Los Alcázares Arenillo, Los Yarumos, and Monteleón) and two immersed in a matrix of urbanization (Jardín Botánico de la Universidad de Caldas and Bosque Popular El Prado). These forest

fragments have the potential to be relevant for bat conservation because their ecological characteristics and connectivity could have an important role in maintaining bat populations, making the city of Manizales and its surroundings areas a potential candidate to be considered an Area of Importance for the Conservation of Bats (AICOMs). This conservation figure proposed by the Latin American and Caribbean Network for the Conservation of Bats (RELCOM in Spanish), is a strategy for the protection of the group, by declaring protected areas of local scope in which bats perform most of their core activities of roosting and foraging (Aguirre and Barquez 2013). AICOMs should meet certain criteria, including high species richness and the presence of shelters, among others (Aguirre and Barquez 2013; Aguirre et al. 2014). Therefore, our objective was to evaluate the potential of these areas as an AICOM based on the high species richness criterion. For this, we consolidated the knowledge on bat richness in sub-Andean and Andean Forest fragments (1700–2600 m), and evaluated the perception, experiences, and knowledge about the role of bats that local people have in the urban and peri-urban area of Manizales.

2 Materials and methods

2.1 Study area

The municipality of Manizales, Department of Caldas, is located on the western slope of the Central Cordillera of the Andes of Colombia. It has an area of 55,000 ha and an elevational range between 800 and 3800 m (Verhelst et al. 2001). The geography includes part of the Middle Basin of the Cauca River and contrasting ecosystems such as sub and high Andean forests, páramos, and snow-capped mountains (Kattan and Álvarez-López 1996). The elevational range, the fertility of the volcanic soils and the hydrographic system, constitute an ecological structure of high value for both agriculture (coffee, banana, and fruit crops) and local biodiversity (Rojas-Morales 2012).

Manizales is the largest and the capital city of the Department of Caldas, with an extension of 571.8 km² and a population of 434,403 citizens (DANE 2018). We chose several sampling points within sub- and Andean Forest remnants located in an elevational range mainly between 1700 and 2500 m. The selected sites were organized into three groups: 1. “Ecoparks” that are protected forested areas inside and around the city of Manizales (Arango-B et al. 2007) and includes: 1.1. Jardín Botánico de la Universidad de Caldas ($n = 5$ sites; 2150 m a.s.l.) with 7 ha, 1.2. Los Alcázares-Arenillo ($n = 5$ sites, 1730–1960 m a.s.l.) with 35.7 ha, both located in the southwestern region of the municipality of Manizales, 1.3. Los Yarumos ($n = 4$ sites; 2153 m a.s.l.) with 35.8 ha located in northeastern Manizales, 1.4. Monteleón ($n = 2$ sites; 2200 m a.s.l.) with 25.9 ha, 1.5 Bosque Popular El Prado ($n = 3$ sites; 2200 m a.s.l.) with 22.7 ha; 2. Peri-urban zone ($n = 9$ sites), that are fragments of vegetation and buffer areas not included in the conservation figures of Ecoparks, for example, the Recinto del Pensamiento “Jaime Restrepo Mejía”

(1750–2250 m a.s.l., with 176 ha located in eastern Manizales), and 3. Urban area ($n = 11$): including the areas immersed in the city that have more buildings than trees in which bats were found. We obtained information of a total of 39 localities among the three groups (Table 1; Figure 1).

2.2 Data collection and species richness

To capture bats, we selected sampling sites in the different localities from September 2018 to February 2020, and again from January to April 2022. We carried out samplings once a week using four mist nets per night (10 and 12 m of length), that were active, on average, from 17 h:30 min to 22:00 h. Mist nets were checked every 10 min or less depending on bat activity at each site and sampling effort was calculated as $\text{m}^2 \text{ mist net} \times \text{hours} \times \text{nights}$. Voucher specimens were deposited at the Colección de Mamíferos del Museo de Historia Natural, Universidad de Caldas (MHN-UCa) in Manizales. To have a comprehensive list that includes species we could not capture during surveys, we reviewed 164 specimens from the study area deposited at the MHN-UCa, collected between 1987 and 2016. We also included incidental captures or dead specimens found mainly by us in the urban area between 2017 and 2021 deposited at the MHN-UCa, and information in the literature (e.g., Castaño et al. 2003a,b; Raigosa Álvarez et al. 2020, Supplementary Table S1). When available, we also obtained reproductive data from the captured and reviewed specimens (e.g., pregnant, lactating, scrotal position of the testes). We identified the specimens using taxonomic keys (Díaz et al. 2021; Gardner 2007). For the specimens captured, we documented their age based on the degree of ossification of the metacarpals (Brunet-Rossinni and Wilkinson 2009). In addition, we took five external and 11 cranial measurements (Gardner 2007; Simmons and Voss 1998) for comparisons with those reported in literature for correct identification. To explore differences in species richness between the sampled areas (Ecopark, peri-urban, or urban zone), we grouped the species captured at the different sites within each zone and calculated the absolute species richness per site (Table 2).

2.3 Local perception and experience about bats

To understand the relationship between residents and their local bat fauna, especially within urban and peri-urban areas, we performed a census following the criteria set out in previous studies (Aziz et al. 2017; da Costa Rego et al. 2015). The questionnaire consisted of open questions and fixed response to obtain data on three main groups of information: (1) sociodemographic; (2) knowledge and perceptions, and (3) experiences.

The questionnaire survey (available in the Supplementary Material) was carried out in Manizales during January 2021–May 2021. Given the public health problems and the preventive isolation caused by the SARS-CoV-2 outbreak in Colombia, it was not possible to conduct interviews directly with people, so we shared a Google form via email and on different social networks such as Facebook, Instagram, and WhatsApp, and on local media such as La Patria newspaper and the official page of the Universidad de Caldas (Buriticá Giraldo 2021).

Respondents' experiences and knowledge about bats and their importance in the city were analyzed using descriptive statistics such as frequencies, averages and percentages, represented by means of absolute frequency graphs made in Excel software. Likewise, the sociodemographic information of the respondents was divided into

categories and summarized in Table 3. To evaluate the influence of socio-demographic data on the perception of bats and their conservation, we performed a Pearson's chi-square test for the categories of sex ($Gl = 1$), age, and level of schooling ($Gl = 2$) with a confidence level of 95 %.

2.4 Evaluation of an Area of Importance for the Conservation of Bats

We evaluated the pertinence of the study area to be declared an Area of Importance for the Conservation of Bats (AICOMs in Spanish) using all the information gathered from the field work and museum research. This conservation figure proposed by the Latin American Network for the Conservation of Bats (RELCOM in Spanish) includes among its criteria (i) the presence of bat species of national or regional conservation interest (threatened and near-threatened species, Data Deficient, endemic, migratory, rare, important role in ecosystem functioning, species with small or restricted ranges), (ii) presence of shelters, and (iii) a high species richness regardless of its threat (Aguirre and Barquez 2013; Aguirre et al. 2014). To evaluate whether the study area meets the third criterion, we compared the local bat richness with that of other localities in the Andean Cordilleras of Colombia with similar elevations. The search was carried out using the combinations of Boolean operators and wild cards in English and Spanish to identify research studies using keywords such as: bats, Chiroptera, Colombia, Cordillera, diversity, richness. The following literature databases were used: PubMed, SciELO, Google Scholar, and Web of Science (all years inclusive).

3 Results

3.1 Bat species diversity and reproductive data

In total for the study area, we identified 33 bat species belonging to 15 genera, and three families (Molossidae, Phyllostomidae, and Vespertilionidae; Figure 2). Phyllostomidae was the most diverse family with 20 species followed by Vespertilionidae with 11 species. Molossidae was only represented by two species. During September 2018 and December 2020 with a sampling effort of 4608 m^2/h -night, we captured 90 individuals representing 12 species. In addition, four species were reported based on incidental captures. Similarly, with a sampling effort of 1620 m^2/h -night in 2022 we captured 78 individuals belonging to 11 species. The review of specimens in collections added 117 records to the check list (Table 2), and five species not reported by us using mist nets or incidental captures.

We found differences in species richness among the sampling sites. The Ecoparks zone presented the highest richness with 25 species with the highest number of species ($n = 16$) at "Los Alcázares Arenillo" and the lowest ($n = 2$) at "Monteleón". The peri-urban zone harboured 10 species and the urban zone only seven species. Some species were only captured in certain sites, for example, within the Ecopark

Table 1: Localities of bat records at the three zones in the municipality of Manizales, Caldas, Colombia.

Locality	Name	Zones	Latitude	Longitude	Elevation (m)
1	Los Alcázares	a	5.06305555	−75.532305	1904–1907
2	Los Alcázares	a	5.0663278	−75.532386	1930–1981
3	Los Alcázares	a	5.06416666	−75.531388	1899
4	Los Alcázares	a	5.0647222	−75.53111	1928
5	Los Alcázares	a	5.0675	−75.53	1933–1944
6	Los Yarumos	a	5.056126	−75.494518	2150
7	Los Yarumos	a	5.0644411	−75.481384	2163
8	Los Yarumos	a	5.0651	−75.4819	2156
9	Los Yarumos	a	5.0641666668	−75.482224	2234
10	Bosque Popular	a	5.0369444	−75.4775	2142
11	Bosque Popular	a	5.0366667	−75.4775	2043
12	Bosque Popular	a	5.0341389	−75.477555	2043
13	Monteleón	a	5.0811111	−75.495555	2043
14	Monteleón	a	5.0780556	−75.4975	2258
15	Jardín Botánico de la Universidad de Caldas	a, c	5.05666	−75.495	2093–2123
16	Jardín Botánico de la Universidad de Caldas	a	5.05666	−75.4941	2095
17	Jardín Botánico de la Universidad de Caldas	a	5.05638	−75.49416	2098
18	Jardín Botánico de la Universidad de Caldas	a	5.056126	−75.494518	2110
19	Jardín Botánico de la Universidad de Caldas	a	5.04666667	−75.49444	2150
20	Recinto del Pensamiento	a	5.0413639	−75.446714	2180
21	Recinto del Pensamiento	a	5.0458333	−75.444833	2300
22	Km 19 Vía al Magdalena	b	5.0538141	−75.445932	2300–2385
23	Reserva Forestal Bosques de la CHEC	b	5.0172	−75.409666	2422–2445
24	Sector Torre 4	b	5.0317222	−75.405194	2520–2656
25	Sector Torre 4	b	5.0253667	−75.38795	2730
26	Vereda Buena Vista	b	5.0544444	−75.471944	2240
27	Vereda Buena Vista	b	5.054727	−75.458639	2225
28	Vereda el Desquite, Corregimiento 7, Reserva Hidrográfica Río Blanco	b	5.0692777	−75.377299	3500
29	Barrio Campo Hermoso	c	5.0772222	−75.526667	2170
30	Barrio Betania**	c	5.054467	−75.497949	
31	Barrio Chipre	c	5.07444444	−75.5275	2150
32	Barrio Chipre, sector parque infantil**		5.0762825	−75.52546	
33	Barrio Fátima**	c	5.053672	−75.494275	2078
34	Barrio La Arboleda	c	5.062222	−75.495	2136
35	Barrio La Arboleda**	c	5.062439	−75.495410	2133
36	Barrio La Cumbre**	c	5.066346	−75.474727	2120
37	Barrio La Enea**	c	5.030390	−75.463947	2083
38	Barrio La Francia	c	5.069444	−75.53055	1986
39	Barrio La Francia, La Arcadia**	c	5.068752	−75.533366	1958
40	Barrio La Leonora, parque Colegio Semenor**	c	5.062513	−75.490894	2125
41	Barrio La Leonora, zona del parque**	c	5.064269	−75.495014	2082
42	Barrio La Montaña, conjunto cerrado**	c	5.051534	−75.527240	2013
43	Barrio La Rambla	c	5.059444	−75.485277	2110
44	Barrio La Rambla, near Universidad Católica**	c	5.0602298	−75.486905	2138
45	Barrio La Suiza, edificio Mirador de La Suiza**	c	5.054326	−75.478324	2167
46	Barrio La Sultana	c	5.063147	−75.469571	2200
47	Barrio La Sultana**		5.060385	−75.473487	
48	Barrio Los Alcázares	c	5.068055	−75.5325	1973
49	Barrio Los Cedros, quebrada Olivares**	c	5.069984	−75.499931	2038
50	Barrio Malabar**	c	5.046119	−75.50080	1937
51	Barrio Milán**	c	5.046381	−75.482617	2200
52	Barrio Palermo	c	5.0525	−75.485555	2150
53	Barrio Palermo**	c	5.051224	−75.486050	2144
54	Barrio San Joaquín**	c	5.065773	−75.514866	2104
55	Barrio San Jorge**	c	5.066963	−75.500511	2106
56	Barrio Urbanización Santos	c	5.053055	−75.5075	1922

Table 1: (continued)

Locality	Name	Zones	Latitude	Longitude	Elevation (m)
57	Barrio Versalles**	c	5.063073	−75.497102	2126
58	Barrio Villa Café**	c	5.062002	−75.482415	2135
59	Barrio Villa Carmenza**	c	5.060601	−75.509066	2000
60	Barrio Villa del Río**	c	5.067164	−75.492422	2047
61	Barrio Villa Pilar**	c	5.085128	−75.527036	2073
62	Edificio Rosales**	c	5.061216	−75.490510	2145
63	Mirador de Estambul**	c	5.054369	−75.527359	2040
64	Mirador San Sebastián**	c	5.086958	−75.494276	2263
65	Sector El Cable	c	5.0558333	−75.485555	2154
66	Universidad de Caldas, Facultad Agronomía	c	5.054583	−75.492389	2180

The zones are: a, Ecoparks; b, peri-urban zone; c, urban area. Barrio = neighborhood. (*) Localities re-sampled in 2022; (**) localities reported by the people surveyed in the city.

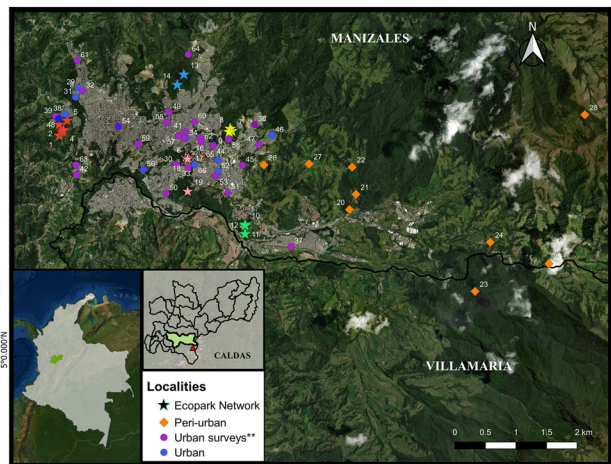


Figure 1: Localities of bat records at the three zones in the municipality of Manizales, Department of Caldas, Colombia. The number of each locality is shown in Table 1. The Ecoparks network: “Los Alcázares-Arenillo” (red star), “Monteleón” (blue star), “Los Yarumos” (yellow star), “Jardín Botánico Universidad of Caldas” (pink star) and “Bosque Popular El Prado” (green star). The peri-urban localities are located between 0.11 and 6.7 km away from the city.

zone, *Carollia castanea*, *Sturnira giannae*, *Enchisthenes hartii*, *Platyrrhinus helleri*, and *Vampyressa thuyone* were only captured in “Los Alcázares Arenillo”, while *Myotis riparius* and *Myotis albescens* only in the “Jardín Botánico”. In the urban zone, only insectivorous species of the families Vespertilionidae and Molossidae were reported. Of the latter family, *Molossus molossus* and *Tadarida brasiliensis* were found even in house roofs (Table 2).

From the collections, 77 specimens of 20 species were reported in the Ecoparks, 27 specimens of 12 species only in peri-urban areas, and 13 specimens of six species in urban areas. From the literature, we added two species from

peri-urban areas (*Sturnira erythromos* and *Histiotus cadenai*) and corrected the identification of five taxa. For example, the records of *Nyctinomops laticaudatus* for the city of Manizales (Castaño et al. 2003b) were re-identified as *T. brasiliensis*. Similarly, the records of *Artibeus jamaicensis* for the Jardín Botánico belong to *Artibeus lituratus* (Castaño et al. 2003a). The records of *Myotis nigricans*, *Myotis oxyotus*, *Eptesicus brasiliensis* and *Platyrrhinus vittatus* reported for the Ecoparks (Raigosa Álvarez et al. 2020) were re-identified as *Myotis caucensis*, *Myotis keaysi*, *Eptesicus furinalis*, and *Platyrrhinus alberticoi* based on morphological and craniodental traits. The recorded species, method (capture, specimen in collection or literature) and locality are presented in Supplementary Table S1. We obtained reproductive data for 13 species including pregnant and lactating individuals, and a female of *Carollia perspicillata* carrying a juvenile in Los Alcázares Arenillo (Supplementary Table S2).

3.2 Local perception and experience about bats

We obtained responses from 219 individuals (128 women, 91 men). The median age of the respondents was 33 years old (range 11–72), and 60.3 % identified themselves as local from the city of Manizales. Most (99.0 %) of the respondents had received some formal education (i.e., secondary school or university), with 86.0 % receiving an education beyond high school. These socio-demographic data of the respondents are shown in Table 3.

We found that the respondents had a good knowledge of what a bat is like and have heard about them through television programs, the internet and family stories (99.0 % of

Table 2: Bat species found at Ecoparks, peri-urban and urban zones in the municipality of Manizales, Caldas, Colombia.

Taxon	Ecoparks					Peri-urban		Eleven urban localities	Elevation (m)
	LY	LAA	JB	ML	BP	Nine localities	RP		
Phyllostomidae									
Carollinae									
<i>Carollia brevicauda</i>	x	x	x			x	x		1907–2300
<i>Carollia castanea</i>		x							1904
<i>Carollia perspicillata</i>	x	x	x		x		x		1553–1930
Glossophaginae									
<i>Anoura caudifer</i>	x	x	x				x		1907–2245
<i>Anoura geoffroyi</i>			x		x				2150
<i>Glossophaga soricina</i>	x	x	x				x		1560–2150
Stenodermatinae									
<i>Artibeus lituratus</i>	x	x	x	x	x				1930–2110
<i>Dermanura bogotensis</i>	x					x	x		1930–2300
<i>Dermanura phaeotis</i>		x					x		1907–1930
<i>Enchisthenes hartii</i>		x							1930
<i>Platyrrhinus helleri</i>		x							1800
<i>Platyrrhinus albericoi</i>		x	x						1907–2300
<i>Platyrrhinus dorsalis</i>	x	x			x		x		1930–2150
<i>Platyrrhinus ismaeli</i>					x				2043
<i>Sturnira aratathomasi</i>							x		2180–2500
<i>Sturnira bidens</i>						x			2445–2547
<i>Sturnira erythromos</i>									2500–3000
<i>Sturnira ludovici</i>						x	x		2180–2500
<i>Sturnira giannae</i>		x							1907–1930
<i>Vampyressa thuyone</i>		x							1907–1930
Vespertilionidae									
<i>Eptesicus chiriquinus</i>		x	x	x	x				1930–2150
<i>Eptesicus furinalis</i>			x			x		x	1922–2240
<i>Eptesicus miradorensis</i>						x	x		2150–2385
<i>Histiotus cadenai</i>						x			3500
<i>Histiotus humboldti</i>			x			x		x	2120–3000
<i>Lasiurus blossevillii</i>			x					x	2108–2150
<i>Myotis albescens</i>			x						2110–2150
<i>Myotis keaysi</i>	x	x				x			1930–3500
<i>Myotis nigricans</i>	x		x					x	2150
<i>Myotis caucensis</i>	x	x	x			x		x	1930–2422
<i>Myotis riparius</i>	x								2150
Molossidae									
<i>Molossus molossus</i>								x	1922–2136
<i>Tadarida brasiliensis</i>								x	2150–2170
Total	11	16	14	2	6	10	10	7	

LY, Los Yarumos; LAA, Los Alcazares-Arenillo; JP, Jardín Botánico; ML, Monteleón; BP, Bosque Popular El Prado. The peri-urban areas include records in the locality Recinto del Pensamiento (RP).

the surveyed sample). Furthermore, 88.6 % have seen bats in urban and peri-urban areas of the city and have some ideas about bats diet. For example, 84.9 % of respondents answered that bats are frugivorous, 60.3 % said nectarivores, and various other food items such as insects were also cited (Figure 3A). Moreover, 75.3 % had knowledge about the spaces used as refuge by bats. The most common

answers were “cave or caverns” with 68 answers, followed by “trees” with 67 answers and finally human structures (i.e., roofs, bridges, abandoned buildings) with 47 answers. Only 23.5 % of respondents did not know the answer.

The majority of respondents (83.1 %) agreed that bats are possible vectors of a wide variety of diseases (Figure 3B). Among these, rabies was the disease most commonly

Table 3: Socio demographic summary of the survey respondents to evaluate the local perceptions about bats in Manizales, Colombia.

	Female	Male
Age (year)		
0–25	60	34
26–50	53	41
>51	15	16
Education		
Full secondary school	15	17
University student	54	28
Professional	59	46
Residence time		
0–20 years	63	12
21–40 years	43	21
> 40 years	22	8
Total	128	91

associated with these mammals with 45.2 % responses, while 21.5 % knew that they transmit zoonotic diseases but were not sure which ones. A positive community attitude towards the conservation of these small mammals was detected with a total of 95.2 % of respondents. In general, the public recognized the importance of bats for the maintenance of natural ecosystems (89.9 %) and control of insect populations that directly affect humans (65.8 %).

The public interviewed also had knowledge about some of the ecosystem services provided by bats in the region, with seed dispersal as the best known (84.0 % of respondents), followed by pollination (82.2 %). Although the survey did not ask for ecological roles, 26.5 % of the respondents emphasized the importance of bats in urban and peri-urban areas as pest controllers. Finally, only 7.8 % and 10.0 % of the 219 surveyed individuals had no knowledge or considered that bats do not fulfill any ecological role and are not important for natural and human environments, respectively.

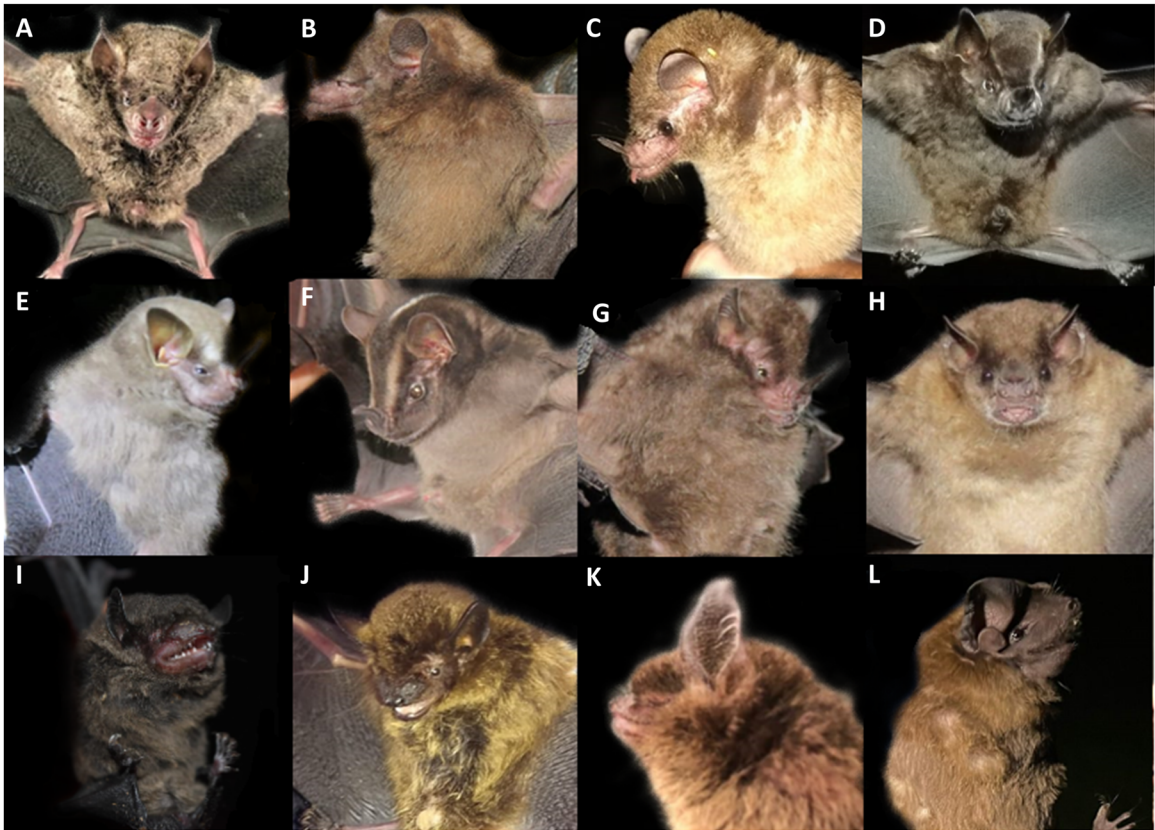


Figure 2: Some bat species of Manizales, Cordillera Central of Colombia: (A) *Carollia perspicillata*, (B) *Anoura caudifer*, (C) *Glossophaga soricina*, (D) *Artibeus lituratus*, (E) *Dermanura phaeotis*, (F) *Platyrrhinus alberticoi*, (G) *Sturnira bidens*, (H) *Sturnira ludovici*, (I) *Eptesicus chiroquinus*, (J) *Eptesicus miradorensis*, (K) *Myotis caucensis*, (L) *Molossus molossus*.

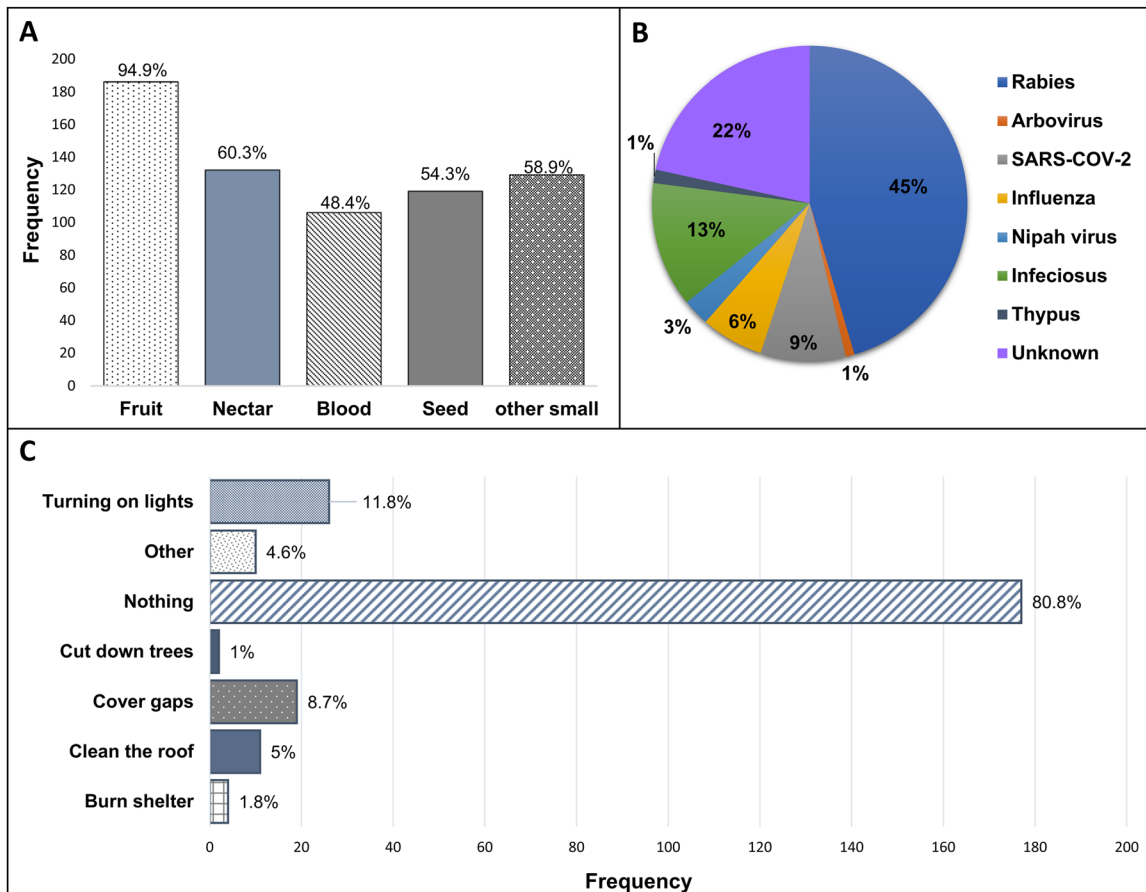


Figure 3: Local perception and human–bat conflict assessment in the city Manizales. (A) Food items consumed by bats, as stated by the respondents, expressed in absolute values. (B) Answers about the knowledge of diseases that can be transmitted by bats, expressed in percentage. (C) Methods used to scare bats away by respondents, expressed in percentage.

3.3 Experience

About the experience with bats, 13.7 % of respondents reported bats in their houses, especially on roofs (56.7 %), chimneys (16.7 %) and urban gardens (26.7 %). Nonetheless, only 2.3 % of them mentioned problems caused by bats in their house including noise and mess/smell from feces in the roof, and fruit raiding. In general, the majority of respondents (61.6 %) knew about some alternatives to mitigate this problem (Figure 3C) including turning on the lights (11.9 %) while other mitigation activities such as the use of ultrasound and direct capture were scarce (4.5 %). Likewise, 44.8 % of respondents indicated the presence of bats in areas near their residence (Table 1; Figure 1).

The statistical analyses did not show significant differences for age ($\chi^2 = 0.46$, $df = 2$, $p = 0.21$; $\chi^2 = 0.87$, $df = 2$, $p = 0.35$), gender ($\chi^2 = 0.13$, $df = 1$, $p = 0.27$; $\chi^2 = 0.82$, $df = 1$, $p = 0.28$), and education level ($\chi^2 = 0.65$, $df = 2$, $p = 0.28$; $\chi^2 = 0.94$, $df = 2$, $p = 0.38$) of the respondents, and their perception of the

ecological role and importance of the conservation of bats in the city, respectively. Likewise, no relationship was found with the negative outlook and fear of disease transmission by bats for none of the three categories ($\chi^2 = 0.58$, $df = 2$, $p = 0.25$, $\chi^2 = 0.82$, $df = 1$, $p = 0.63$, and $\chi^2 = 0.84$, $df = 2$, $p = 0.341$).

In addition, of the 33 species reported in this study, only five (*E. furinalis*, *Histiotus humboldti*, *Lasiurus blossevillei*, *Molossus molossus*, and *T. brasiliensis*) were recorded by us in human houses and other buildings. Most of the reports were fortuitous encounters of the bats in human settlements or bats captured by domestic animals (mainly domestic cats). Despite that, we did not find bat colonies in the city of Manizales.

3.4 Evaluation of an Area of Importance for the Conservation of Bats

The search for studies on Andean bats in Colombia in an elevational range between 1750 and 3700 m, yielded 11

Table 4: Number of bat species detected in 11 studies at the elevations over 1750 m a.s.l. in the three Cordilleras of the Andes of Colombia.

Department	Cordillera	Richness	Elevation (m)	References
Antioquia	Central Cordillera	8	1500–2500	Muñoz Arango (1990)
Caldas	Central Cordillera	6	2150	Castañó et al. (2003ab)
Caldas	Central Cordillera	8	2500–3500	Rodríguez-Posada (2010)
Caldas	Central Cordillera	20	1750–2250	Raigosa Álvarez et al. (2020)
Cauca	Central Cordillera	15	1750–1850	Ramírez-Chaves and Pérez (2007)
Cauca	Central Cordillera	19	1750–2880	Ramírez-Chaves et al. (2008a)
Risaralda	Central Cordillera	20	1800–2100	Estrada-Villegas et al. (2010)
Tolima	Central Cordillera	22	1900–4000	Bejarano-Bonilla et al. (2007)
Cundinamarca	Oriental Cordillera	11	1700–2000	Daniel Ferreira (2009)
Cundinamarca	Oriental Cordillera	12	2750–2850	Pérez-Torres and Ahumada (2004)
Valle del Cauca	Occidental Cordillera	22	1850–2100	Ferro Muñoz et al. (2018)

studies that can be used for comparison (Table 4). The studies were done in the departments of Antioquia, Cauca, Caldas, Cundinamarca, Risaralda, Tolima, and Valle del Cauca. The number of species documented in these studies ranges between six and 22 species. When combined, 24 species are registered in elevations between 1600 and 1900 m, and 13 species in elevations between 2660 and 3700 m (Table 4). Manizales and its peri-urban area (including the Ecoparks) houses a high richness of bats in the evaluated elevational range and offers resources to perform most of their core activities of roosting and foraging. For that reason, the study area meets two conditions to be considered an Area of Importance for the Conservation of Bats (AICOMs).

4 Discussion

With 33 confirmed species our results demonstrate the presence of high levels of bat diversity for the urban and peri-urban area of Manizales. All the information collected in the present study suggests that the Andean ecosystems and urban area of Manizales constitute a potential candidate to be considered an Area of Importance for the Conservation of Bats (AICOMs). This could also be relevant for the establishment of municipal or regional policies towards bat – and other vertebrates – conservation. Furthermore, to date, only six AICOMs have been recognized in Colombia, and this would be the first one protecting bats in intermediate elevations of the Cauca River Basin of Colombia.

The bat richness, the presence of pregnant and lactating females in the study area suggests that the Andean forests present in the peri-urban areas as well as the forests fragments inside and around the city provide sufficient resources and habitats for the persistence and maintenance of bat populations. The composition of species,

genera and families is similar to other studies performed in similar ecosystems and elevations (Fleming 1986; Graham 1983). Similarly, the bat assemblage is represented by widespread generalist frugivores (e.g., some species of *Carollia*, *Artibeus*, *Sturnira*, and *Platyrrhinus*), nectarivores (*Anoura*, *Glossophaga*), some taxa with specialized habits typical of preserved Andean forests such as those of the genus *Vampyressa* and *Enchisthenes*, and some highland insectivores (e.g., some taxa of *Eptesicus* and *Myotis*).

The high richness of fruit-eating bats (Phyllostomidae) can be attributed to the presence of forest fragments within the city and the peri-urban areas such as the Ecoparks network, that are providing sufficient resources (food and shelter) for these species, which in turn contribute to the maintenance of these fragments through seed dispersal (Lobova et al. 2009). Other bats found in lower proportion are insectivores (Vespertilionidae and Molossidae) which are commonly less recorded with conventional methods such as mist-nets, and the richness of these bats in the study area might be higher. The implementation of additional detection methods (e.g., acoustic calls recording) might increase the number of insectivorous species that play an important role in cities as they contribute to the biological control of pests (Kalka et al. 2008). Both insectivore families included some common species such as *Molossus molossus* (Molossidae), and *M. caucensis* (Vespertilionidae) found in urban areas inhabiting the roofs of houses or building crevices (Alberico et al. 2005; Sampedro-Marín et al. 2008), and less documented species such as the recently described *H. cadenai* (Vespertilionidae) which type locality is at the Vereda El Desquite within the Río Blanco Reserve in Manizales (Rodríguez-Posada et al. 2021), to date only present in protected areas.

Our results are also key to update the number of bat species for the city of Manizales by increasing the sampling effort in urban and peri-urban areas that had not been considered in previous studies. For example, for the Jardín

Botánico at the Universidad de Caldas, only six species were previously registered (Castaño et al. 2003a), with a sampling effort of 72 mist net-hours. In our study, we documented 12 species (240 mist net-hours effort in 2018–2020 and 720 mist net-hours effort in 2022). Likewise, it was possible to increase the number of species present in the Ecoparks (25 species vs. 20 species in Raigosa Álvarez et al. 2020) including two localities (Monteleón and Bosque Popular El Prado) not previously sampled in the city of Manizales. We also excluded some species reported in previous works that were misidentified or lacked voucher specimens. Finally, other studies carried out in areas whose altitudinal ranges are similar to those of Manizales (Bejarano-Bonilla et al. 2007; Daniel Ferreira 2009; Estrada-Villegas et al. 2010; Ferro Muñoz et al. 2018; Pérez-Torres and Ahumada 2004; Ramírez-Chaves and Pérez 2007; Ramírez-Chaves et al. 2008a; Rodríguez-Posada 2010), have documented between six and 22 species (Table 4), corroborating the high richness of bats in Manizales.

The finding of only five species in buildings or houses and the relative low abundance of individuals in the study area and near localities of the Central Andes (e.g., Cepeda-Duque et al. 2021; Ramírez-Chaves et al. 2020c) shows that encounters between the human community and bats are probably rare in Manizales. Even though bat colonies in human settlements can generate discomfort due to noise and accumulation of excrement (Ramírez-Chaves et al. 2008b; Sampedro-Marín et al. 2008). We found that when most of the surveyed individuals recognize their presence in areas near to houses, they prefer not to do anything to drive them away. Moreover, they are not aggressive towards bats, as regardless of age, schooling status or sex, all of them recognize the importance and the role that these mammals play in maintaining ecosystems. Surveys have served as a strategy to determine the perceptions and local knowledge that people have about bats and the results have been used for environmental education activities in former studies (Giraldo Mora 2018; Navarro-Leal 2019). In Colombia, surveys including similar number of participants but taken in mid and lower elevations of tropical dry forests, have evaluated human–bat interactions to contribute to the conservation of bats in the country and to reduce conflicts between people and bats (Ramírez-Francel et al. 2021). Thus, we believe that the role of bats in Manizales might be well understood in the population based on the collected interviews (with the implementation of additional socialization of the ecological role of the bats), and this can be relevant for the implementation of environmental education programs in favor of bats and for the strengthening conservation plans and supporting the establishment of the AICOM. Furthermore, although surveys have been used to evaluate people knowledge about bats in other South American countries

(Aziz et al. 2017; da Costa Rego et al. 2015), in Colombia these have not been widely used and should be considered when exploring strategies towards bat conservation.

Research ethics: The bats were collected and handled under the permit granted by the Autoridad Nacional de Licencias Ambientales (ANLA) to the Universidad de Caldas (Resolution 02497, of December 31, 2018) and by approval of the bioethics committee of the Facultad de Ciencias Exactas y Naturales of the Universidad de Caldas (June 2, 2017). All procedures were in accordance with the national laws.

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