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Urban Remnant Forests: Are They Important for Herpetofaunal Conservation in the Central Andes of Colombia?

Human population growth is associated with an increasing demand for natural resources, which, in turn, requires the transformation of forested landscapes into open areas for agriculture and establishment of urban environments (Forman 1995). At present, more than half of human populations are living in urban areas, and urban populations continue to grow. The effect of urbanization on biodiversity is complex: while many studies have found a negative relationship between urbanization and species richness (Niemela et al. 2002; Gagné and Fahrig 2006; Garden et al. 2006), others have found the opposite tendency (Araujo 2003; Evans and Gascon 2005; Luck 2007; but see Luck 2010). Because our understanding of the effect of urbanization on a species depends both on its natural history and on the spatial and temporal scale of a study (Chase and Walsh 2006; Luck and Smallbone 2010), patterns can be hard to generalize to poorly studied regions and species. Thus, data on the response of a variety of species to the environmental changes imposed by urbanization and how the remnant natural areas could ameliorate negative effects are needed (McKinney 2006; Slabbekoorn and Ripmeester 2008; Gil and Brumm 2014).

In Latin America, interest in biodiversity dynamics in urban habitats has grown in the last two decades, but there are still many gaps in our knowledge about the biota that can persist in highly

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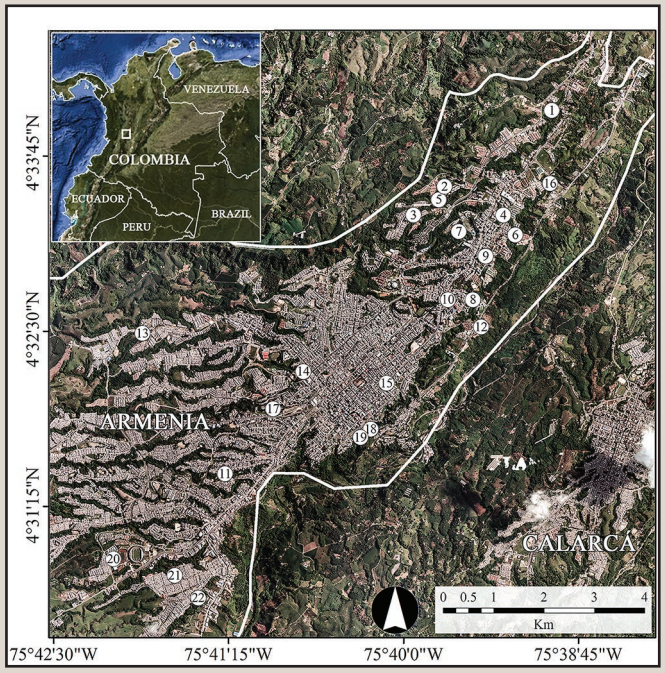

Fig. 1. Urban forest remnants sampled in the city of Armenia, Quindío, Central Andes of Colombia. Record place code: **1.** Barrio El Paujil, **2.** Barrio El Tintal, **3.** Barrio Mercedes del Norte, **4.** Hospital San Juan de Dios, **5.** Conjunto Proviteq, **6.** Quebrada La Aldana, **7.** Jardín Botánico de la Universidad del Quindío, **8.** Parque de la Vida, **9.** Barrio La Castellana, **10.** Parque Fundadores, **11.** Barrio Nueva Cecilia, **12.** Barrio Centenario, **13.** Barrio La Patria, **14.** Parque El Bosque, **15.** Parque Sucre, **16.** Quebrada La Florida Norte, **17.** Ferrocarril Antiguo, **18.** Barrio La Florida, **19.** Quebrada La Florida, **20.** Hospital del Sur, **21.** Bosques de Pinares, **22.** Barrio Pinares. White line in the largest plot indicates limits of the city of Armenia.

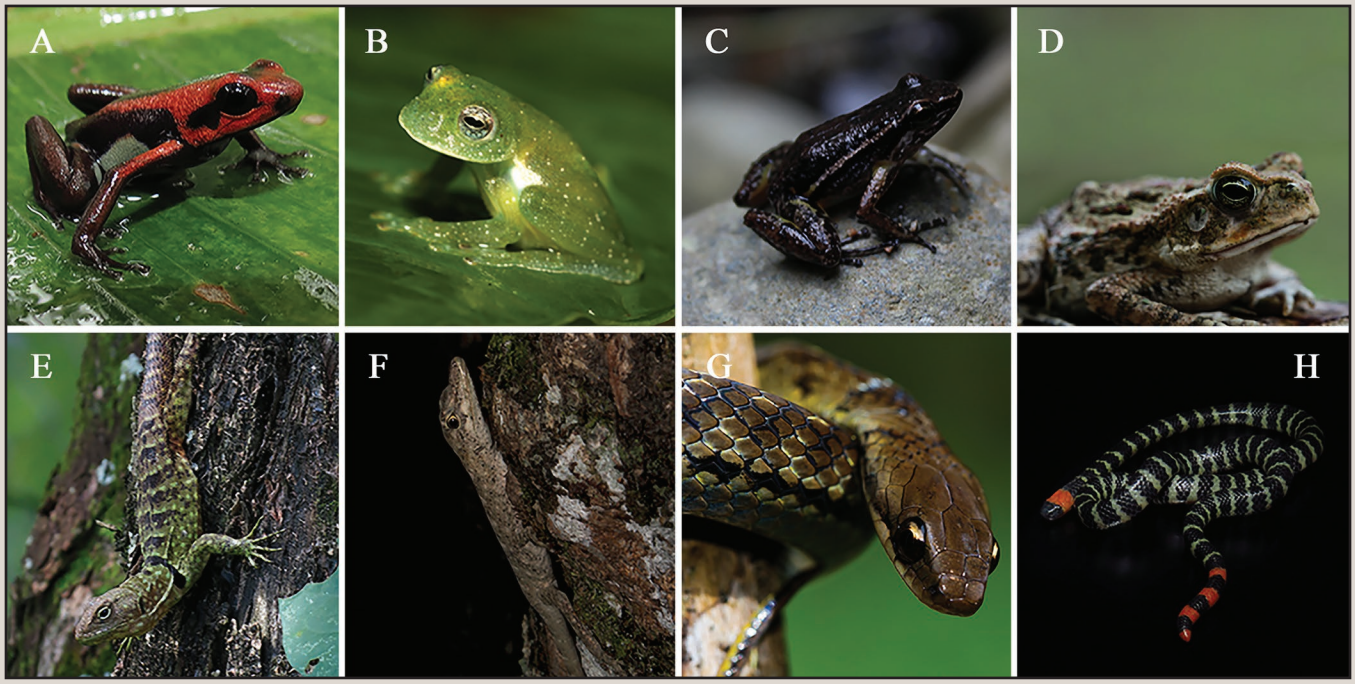

FIG. 2. Some amphibians and reptiles recorded in the city of Armenia, Central Andes of Colombia. A) *Andinobates bombetes,* B) *Centrolene savagei,* C) *Colostethus fraterdanieli,* D) *Rhinella marina,* E) *Stenocercus bolivarensis,* F) *Anolis antonii,* , G) E*rythrolamprus epinephelus* H) *Micrurus mipartitus.* Photos: Jhonattan Vanegas (B, C, D, E, F, G), Wolfgang Buitrago (A, H).

urbanized landscapes (reviewed in Delgado-C and Correa-H 2013; MacGregor-Fors and Ortega-Alvares 2013). In particular, the Colombian Andes are recognized as a region with a high diversity of species, many of which are highly endemic or have limited geographical distributions (Pérez-Santos and Moreno 1988; Kattan et al. 2004; Bernal and Lynch 2008); however, the Andes is also one of the most urbanized regions in the country (Andrade-Medina and Bermúdez-Cárdenas 2010). Therefore, it is important to document the diversity in the fauna that persists in natural habitats embedded in urbanized areas of Colombian Andes; this information may give us baseline data for optimizing management plans (Niemelä 1999).

Amphibians and reptiles may be more affected by urbanization than other vertebrates because of their ectothermic physiology, their low vagility, the negative perception of some species by humans (e.g., snakes), and in the case of amphibians, their reliance on humid habitats for reproduction (Gagne and Fahrig 2006; Mitchell et al. 2008; Secco et al. 2014). Published studies about urban herpetology in Colombia are few. Some studies list species in urban habitats (Bernal 2002; Arce et al. 2010; Chaves et al. 2010; Bólivar-Garcia 2011; Ramírez-Saboyá-Acosta et al. 2015), while others document mortality and changes in structure and composition of assemblages as a consequence of urban structures such as roads (Vargas-Salinas et al. 2011; Lynch 2012; Rojas-Morales 2012; Quintero-Ángel et al. 2012). Here, we document the herpetofaunal diversity present in urban remnant forests of Armenia, a medium-sized city (250 km^2, >297.000 people; DANE 2005) located in the department of Quindío, Central Andes of Colombia. Although some biotic inventories in urban-matrix embedded forest remnants in this region are available (Salazar et al. 2005; Méndez-Rojas et al. 2009; Armas and Delgado-Santa 2012), no data about herpetofaunal diversity have been published.

Materials and Methods.—The city of Armenia (Quindío department) is located on the western slope of the Central Andes of Colombia (4.516667°N, 75.66666°W; 1483 m elev.). The average annual temperature of Armenia is 22°C, with a high average relative humidity of 80.9%; precipitation is seasonal, with approximately 2119 mm/year rainfall (IDEAM 2014). The remaining forest remnants in the urban matrix of Armenia cover 9580 km^2, and represent 30% of the total area of the city (CRQ-SIG 2014).

Between March 2009 and February 2015, we sampled the 22 largest urban forest remnants with clear borders defined by artificial barriers (Fig. 1). We conducted diurnal (0900–1200 h) and nocturnal samplings (1900–2200 h) using visual encounter surveys (Heyer et al. 1994); in total, our sampling effort for the study was 522 person-hours. In addition, we included casual and opportunistic records made by the authors, other herpetologists, and records in the herpetological museum of the Universidad del Quindío (Herpetos-UQ; Appendix I). We used the taxonomic nomenclature from Frost (2015) for amphibians, and Uetz and Hošek (2015) for reptiles. All collected specimens were deposited in the Herpetological collection of the Universidad del Quindío in Armenia, Colombia (Appendix I).

Results.—We observed 29 species (7 amphibians, 22 reptiles) of 23 genera and 15 families (Table 1), demonstrating that these urban forest fragments support more than 39% of the known herpetofaunal richness for the department of Quindío (Vanegas-Guerrero et al. 2014, 2015a,b; Acosta-Galvis 2015). Eight species are endemic to Colombia, and seven are considered threatened or near threatened by Rueda-Almonacid et al. (2004) and IUCN (www.iucn.org/es). The lizard *Stenocercus bolivarensis* (Fig. 2E) has few previous reports in the literature (Vanegas-Guerrero et al. 2015b), and six other reptiles are reported by the first time for the department of Quindío (Fig. 3): the invasive geckos *Hemidactylus angulatus* (Herpetos-UQ 54, 269, 313, 417, 556–

TABLE 1. Checklist of amphibians and reptiles in urban forest remnant in the city of Armenia, Central Andes of Colombia. Threat category (TC) according to Rueda-Almonacid et al. (2004) and IUCN (2014): Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Not Assessed (NA). Species endemic (E) to Colombia are marked with ♦. Record Place Codes correspond to forest fragments in Fig. 1.

Taxon	TC	E	Record Place Code
ANURA			
Bufonidae			
Rhinella marina (Linnaeus, 1758)	LC		3, 4, 5, 6, 13, 19
Centrolenidae			
Espadarana prosoblepon (Boettger, 1892)	LC		7
Centrolene savagei Ruíz-Carranza and Lynch, 1991*	VU	♦	7
Craugastoridae			
Pristimantis achatinus (Boulenger, 1898)	LC		1, 2, 3, 4, 5, 6, 7, 8, 13, 14, 16, 19, 20, 21, 22
Dendrobatidae			
Andinobates bombetes (Myers and Daly, 1980)	EN	♦	1
Colostethus fraterdanieli Silvestone, 1971	NT	♦	2, 3, 4, 5, 7, 13
Hylidae			
Dendropsophus columbianus (Boettger, 1892)	LC	♦	2, 3, 5, 8, 10, 15, 16, 19, 21, 22
SERPENTES			
Anomalepididae			
Anomalepis sp.	—	—	7
Colubridae			
Clelia equatoriana (Amaral, 1924)	NA		Av. Centenario**
Mastigodryas boddaerti (Sentzen, 1796)	NA		Patio Bonito**, 7, 17, 19
Spilotes pullatus Linnaeus, 1758 †	NA		7
Tantilla melanocephala (Linnaeus, 1758)	NA		3, 13, Cra 13 - Cll 9N**
Dipsadidae			
Atractus sp.	NA		11
Atractus obesus Marx, 1960	NA	♦	Colegio Cristóbal Colon**
Erythrolamprus epinephelus (Cope, 1862)	NA		7
Imantodes cenchoa Linnaeus, 1758	NA		13, Av. Centenario**
Leptodeira annulata (Linnaeus, 1758)	NA		7
Oxyrhopus petolarius (Linnaeus, 1758)	NA		7
Elapidae			
Micrurus mipartitus (Duméril, Bibron and Duméril, 1854)	NA		18, 19, Av. Centenario**
LACERTILIA			
Dactyloidae			
Anolis antonii Boulenger, 1908	NA	♦	4, 7, 9, 11, 12, 13, 18, 19
Gekkonidae			
Hemidactylus angulatus Hallowell, 1854	NA		2, 3, 5, 4, 12
Hemidactylus frenatus Duméril and Bibron, 1836	NA		15
Lepidodactylus lugubris (Duméril and Bibron, 1836)	NA		Plaza de Bolívar**
Iguanidae			
Iguana iguana (Linnaeus, 1758)	NA		5, 7, 8, 10, 15
Sphaerodactylidae			
Gonatodes albogularis (Duméril and Bibron, 1836)	NA		B/ Siete de Agosto**
Lepidoblepharis duolepis Ayala and Castro, 1983	NA	♦	2, 5, 7, 3
Tropiduridae			
Stenocercus bolivarensis Castro and Ayala, 1982	NA	♦	7
TESTUDINES			
Emydidae			
Trachemys callirostris (Gray, 1855) •	NT		5, 8
Cryptochelys leucostoma (Duméril and Bibron, 1851) •	NA		13, 8

*Data courtesy of María Camila Basto and Jhulyana López; † data courtesy of Gerardo Ramos Valdes; • data courtesy of Alejandra Bedoya; ** opportunistic records.

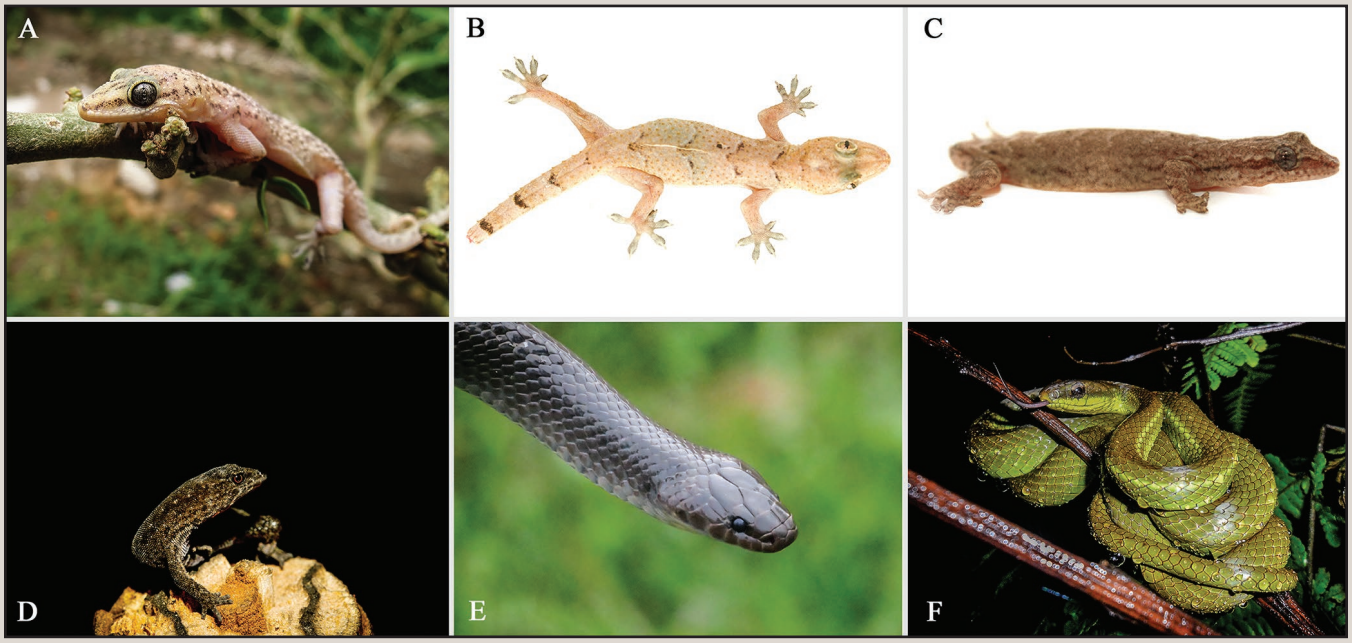

FIG. 3. Image of reptiles registered for the first time in the department of Quindío, Central Andes of Colombia: A) *Hemidactylus angulatus*, B) *Hemidactylus frenatus*, C) *Lepidodactylus lugubris* (HerpetosUQ-0416), D) *Lepidoblepharis duolepis*, E) *Clelia equatoriana*, and F) *Mastigodryas boddaerti*. Photos: Carlos M. Gómez (F), Jhonattan Vanegas-Guerrero (B, C, D), Luis Vera (E), Wolfgang Buitrago (A).

559), *Hemidactylus frenatus* (Herpetos-UQ 0311–0312), and *Lepidodactylus lugubris* (Herpetos-UQ 0416), the native gecko *Lepidoblepharis duolepis* (Herpetos-UQ 315, 541, 565–567), and the snakes *Clelia equatoriana* (Herpetos-UQ 0249) and *Mastigodryas boddaerti* (Herpetos-UQ 0049, 0238, 0331).

Habitat use was variable among species. Amphibians were observed above herbaceous and scrub vegetation or among forest litter; most species were associated with bodies of water and males were commonly heard calling, especially after rains. Snakes were observed commonly on the edges of trails and open areas, while lizards primarily were recorded upon vegetation and tree trunks (Dactyloidae, Iguanidae, Tropiduridae), forest litter and rocks (Sphaerodactylidae), or associated with human buildings (Gekkonidae).

Discussion.—Amphibian richness was lower than reptile richness which coincides with findings by other authors in urban areas both regionally in Colombia (Armesto 2009, 2011; Arce et al. 2010; Rojas-Morales 2012; Saboyá-Acosta et al. 2015) and globally (Dawson and Hostetler 2008; Hamer and McDonnell 2010). This pattern may be attributable to the high sensitivity of amphibians to alkalinity of substrates used for road and house construction, and to their dependence on humidity and bodies of water for survival and reproduction (Duellman and Trueb 1994; Forman et al. 2003). In contrast, reptiles are more independent of environmental humidity and bodies of water than amphibians because of their scaled body cover and reproductive biology (i.e., amniotic egg) (Vitt and Caldwell 2014).

Many species of amphibians and reptiles in the Colombian Andes are negatively affected by agricultural practices and habitat loss. As a result, their populations have been increasingly restricted to smaller and more isolated forest remnants (Rincón and Castro 1998; García et al. 2007; Cortés et al. 2008; Hoyos-Hoyos et al. 2012). Grasslands and disturbed habitats used for agricultural production dominate the landscapes around the study area (Cultid et al. 2012; Hoyos-Hoyos et al. 2012); hence, our records of threatened species suggests a high importance of urban forest remnants for regional herpetofaunal conservation, an implication that is corroborated by a variety of studies of forest remnants embedded in agricultural landscapes (Turner and Corlett 1996; Pascarella et al. 2000; Kattan et al. 2006).

One of the aspects that can influence the persistence of populations and the diversity of species in forest remnants is the degree and time of isolation of the forest patch (Schelhas and Russell 1996; Laurance and Bierregard 1997). At present, we do not have detailed information about urbanization growing patterns in Armenia that allows us to calculate the degree and time of isolation for each urban forest included in this study. However, some neotropical amphibians could found abundant resources (e.g., food, breeding sites) in small forest remnants and therefore, their populations being locally abundant and apparently viable for long time (Becker et al 2007, but see Zimmerman and Bierregaard 1983). The record of rare species such as the lizard *Stenocercus bolivarensis* and breeding behavior in frogs (*Espadarana prosoblepon, Dendropsophus columbianus, Pristimanthis achatinus, Colostethus fraterdanieli*), suggest that urban forest remnants in the study area offers adequate habitats at least for some species. Further studies are necessary to test which species may be of lower concern or especially prone to local extinction.

In addition to threatened species, some recorded species warrant special attention in eventual educational and monitoring plans. First, although the coral snake *Micrurus mipartitus* (Elapidae) is secretive and rarely observed, it is brilliantly colored and highly venomous (Campbell and Lamar 2004); thus citizens should be educated to avoid handling of this snake. In addition, the geckos *Hemidactylus angulatus, H. frenatus,* and *Lepidodactylus lugubris* (Fig. 3) are highly invasive and may have negative effects on native populations through competition for resources (Case et al. 1994; Castaño-Mora 2000; Caicedo-Portilla and Dulcey-Cala 2011).

Preliminary results in urban forest remnants at municipalities near our study area (Calarcá, 4.344444°N, 75.561111°W and 4.563889°N, 75.811111°W; see Fig. 1) include several species that were not observed in this study: the frog *Pristimantis* sp., the lizards *Cercosaura vertebralis*, *Riama columbiana*, the snakes *Atractus* sp., *Dendrophidion bivittatus,* and the turtle *Rhinoclemmys melanosterna*. Consequently, it is possible that our results underestimate the herpetofaunal diversity in the urban forest fragments we studied and therefore the conservation value of those remnants; future sampling of new areas will help improve estimates. Further studies also should standardize methodologies and sampling effort among forest remnants in a way that makes quantitative analysis between forests attributes and species diversity feasible. We hope our study promotes more research about biotic assemblages in urban areas of Colombia and the Neotropics.

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Appendix I

Specimens recorded in urban forest remnant in the city of Armenia, Central Andes of Colombia and deposited in the Herpetological Collection of the Universidad del Quindío (Herpetos-UQ). ***Anolis antonii***: 0033, 0094, 0250, 0251, 0252, 0266; ***Anomalepis* sp.:** 106; ***Atractus* sp.**: 363, 364; ***Clelia equatoriana***: 0249; ***Colostethus fraterdanieli***: 0244, 0406; ***Espadarana prosoblepon***: 0243, 0390, 0391; ***Hemidactylus angulatus***: 0054, 0313; ***Hemidactylus frenatus***: 0417; ***Iguana iguana***: 0197; ***Lepidoblepharis duolepis***: 0264; ***Mastigodryas boddaerti***: 0049, 0238, 0331; ***Micrurus mipartitus***: 0048, 0071, 0124; ***Pristimantis achatinus***: 0149, 0245, 0246, 0247, 0248, 0265, 0392; ***Stenocercus bolivarensis***: 0282; ***Tantilla melanocephala***: 0227, 0314.