



A new species of harlequin frog (Bufonidae: *Atelopus*) with an unusual behavior from Andes of Colombia

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Abstract

A new species of harlequin frog, genus *Atelopus*, is described from the highlands in the northern part of the Cordillera Central, Colombia. The new species, is distinguished from all other species in the genus by the presence of a postorbital crest widely raised, well defined *coni* in postocular region and arms, small warts and spiculae scattered on the dorsal surfaces of the body and thighs and, vertebral neural processes conspicuous. Females are uniform dark reddish brown on dorsum, and bright orange ventrally; males are dark brown dorsally, and ventrally white or yellowish with dark brown irregular stripes and blotches. The conservation population status of the new species is discussed, additionally the natural history and aspects about an unusual behavior in the genus is provided.

Key words: *Atelopus nocturnus* **sp. nov.**, Cordillera Central, Colombia, natural history, taxonomy

Resumen

Describimos una nueva especie de rana arlequín del género *Atelopus* de tierras altas en el norte de la Cordillera Central de los Andes de Colombia. La nueva especie se distingue de las otras especies del género por la presencia de una cresta postorbital ampliamente levantada, *coni* en la región posterior al ojo y en los brazos, pequeñas verrugas y tubérculos en la superficie dorsal del cuerpo y muslos, y proceso vertebral neural visible. Las hembras son café rojizo uniforme en el dorso y naranja brillante en el vientre; en machos el dorso es café oscuro y vientre blanco o crema amarillento con manchas irregulares café oscuro. Discutimos el estatus de conservación de la nueva especie, además, proveemos aspectos de la historia natural y de un comportamiento inusual en el género.

Palabras clave: *Atelopus nocturnus* **sp. nov.**, Cordillera Central, Colombia, historia natural, taxonomía

Introduction

Although some species are found only in biological collections, the genus *Atelopus* still is one of the most diverse and conspicuous components of the neotropical anurofauna. This is the richest among the toads to family Bufonidae currently containing 94 described species (Frost 2011), has diurnal activity (Rueda *et al.* 2005, Lötters 2007, Coloma *et al.* 2002) and due to its bright color commonly referred to as harlequin frogs. *Atelopus* live at or in the margins of streams and running water is utilized for reproduction (Lötters 2007), and most species occur in mountain habitats above 1500 m (see Lötters 1996; IUCN 2010). Apparently due to association with the streams and the physiognomy of the Andes has resulted in restricted area of distribution of species (Lötters 1996; La Marca *et al.* 2005), and has promoted diversification in this genus. Throughout Central and South America, 97% of the species of the genus are regarded as Endangered, Critically Endangered or Extinct, according to IUCN Red List criteria (Stuart *et al.* 2008), because populations are known to have declined dramatically (e.g. Ron *et al.* 2003, La Marca

et al. 2005). Currently, 42 species of *Atelopus* are recognized for Colombia (Frost 2011) being the most diverse country for genus. However, the taxonomy of the genus in Colombia is still poorly understood and at least eight new undescribed species were reported by Rueda *et al.* (2005). During a field trip in 2003 to the highlands of the northern Cordillera Central, Colombia, members of Grupo Herpetológico de Antioquia collected a specimen of *Atelopus* while sleeping in a bush during daylight hours. Subsequent searches in the following years in this area were unsuccessful until 2007 when 12 additional specimens were observed active at night (which was collected eight). Comparisons with museum specimens, original descriptions and other literature revealed that our specimens belong to an undescribed taxon. The goal of this paper is formally describe this new species of *Atelopus*.

Material and methods

The type specimens of the new species are deposited in the Museo de Herpetología, Universidad de Antioquia (MHUA), Medellín, Colombia. Comparisons were made with the original descriptions of other *Atelopus* species and in some cases with specimens available in herpetological collections (i.e. ICN - Instituto de Ciencias Naturales, Universidad Nacional de Colombia and MHUA, Appendix I). Throughout the text, we use the term “spiculae” to refer to pustular warts and “coni” to refer to spiculae with pointed projections (Duellman and Trueb 1986; Coloma *et al.* 2002). Sexual maturity was determined by the presence of eggs or convoluted oviducts in females, and by the presence of nuptial excrescences covering the dorsum of finger I in males, and also by amplexus when it was observed in the field. Measurements (adults only) were taken following Gray and Cannatella (1985), with some additional measures. Abbreviations of measurements are SVL (snout–vent length), TIBL (tibia length), FOOT (foot length), HLQS (head length from the squamosal to tip of snout), HDWD (head width at the widest point), SW (sacrum width: the length from the outer margin of the sacral diapophysis to the outer margin of the contralateral side), NSD (nostril–snout distance), EYDM (eye diameter), EYNO (eye to nostril distance), IOED (inter-orbital external distance), IOID (inter-orbital internal distance) ITND (internarinal distance), FAL (length of flexed forearm), HAND (hand length from proximal edge of outer metacarpal tubercle to tip of finger III), THBL (thumb length from outer metacarpal tubercle to tip of finger I), and FL (femur length). Measurements of frogs were made to the nearest 0.1 mm with Mitutoyo digital calipers. Webbing formulae are indicated in the manner of Savage and Heyer (1969), with modifications suggested by Myers and Duellman (1982) and Savage and Heyer (1997). The webbing formula is a subjective approximation, because in some cases the distinction between webbing and lateral fringes is ambiguous; in such cases, a range is indicated when a single specimen is described. In the diagnoses, a range also indicates intraspecific variation. Colors and patterns description are based on photographs taken in the field and field notes. Drawings were made using a camera lucida attached to a Wild M3 Heerbrugg stereo-microscope.

Atelopus nocturnus, sp. nov.

(Figures 1–6)

Holotype. MHUA 5280, adult female, from Reserva Natural “Arrierito Antioqueño” (06 58.842 N, 75 06.738 W), quebrada El Oso, vereda El Roble, municipio de Anorí, Departamento de Antioquia, Colombia, 1670 m elevation, collected by Laura Bravo-Valencia, Claudia Molina and Natalia Silva on 15 February 2007.

Paratopotypes. MHUA 5279, same data as holotype. MHUA 5281, 5282 (cleared-and-stained preparation), 5283–84, 5286, adult males, and MHUA 5285, adult female, all obtained from type locality by Laura Bravo-Valencia and Claudia Molina on July 2007.

Paratypes. MHUA 2472, adult male, from Bosque El Chaquiral (0659'N, 7507'W), vereda El Retiro, municipio de Anorí, Departamento de Antioquia, Colombia, 1875 m elevation, collected by Jenny Urbina and Sandra Galeano on 12 February 2003.

Diagnosis. This species described here is assigned to *Atelopus* because it has the combination of characters diagnostic of the genus (*sensu* McDiarmid 1971, Lynch 1993, Lötters 1996): head usually longer than broad, with the snout strongly acuminate from above and typically acute in lateral view, the lateral nares are close to the tip of the snout, an external tympanum absent, a prominent supratympanic crest present, first digit of the hand is reduced,

evident sexual dimorphism in size and color, axillary amplexus, arboreal habits and individuals associated with streams. In addition, to lack the terminal phalange in the thumb (observed in the specimen cleared-and-stained, MHUA 5282). *Atelopus nocturnus* (Fig. 1, 2A), is a harlequin frog distinguished from other species of *Atelopus* by the following combination of characters: (1) A moderate-sized species (SVL in females 33.0–34.3, $n = 3$; males 20.1–25.0, $n = 6$); (2) hind limbs short ($TL/SVL = 0.40\text{--}0.43$, $n = 9$); (3) phalangeal formula of hand 1–2–3–3, basal webbing present; (4) foot webbing formula I (0–0) — (0⁺–1[–]) II (0–0) — (1^{1/2}–1^{3/4}) III (0–0⁺) — (2–3) IV (2–3) — (0–0⁺) V; (5) snout acuminate, protruding beyond lower jaw; (6) tympanic membrane, tympanic annulus and stapes absent; (7) dorsal surfaces of body bear a few scattered small warts and spiculae; (8) white coni over warts (cream in preservative) present on arm and postocular region; (9) postocular crest and vertebral neural processes conspicuous; (10) dorsum dark reddish brown to orange-brown on the flank surfaces in females, dorsum and flank surfaces dark brown in males; (11) venter uniform bright orange in females (cream in preservative) and white to cream in males with dark brown irregular stripes and blotches; (12) throat and ventral region smooth in females, and skin below vent areolate in males; (13) palmar hand and plantar foot dark orange in females and light orange in males; (14) iris bright yellow with fine reticulation and spots in brown and black.



FIGURE 1. *Atelopus nocturnus* **sp. nov.** (MHUA 5280, holotype; adult female in life, SVL = 33.0 mm). Photograph by L. Bravo-Valencia.

Comparison with congeneric species. The diagnostic characters readily distinguish *Atelopus nocturnus* from the all described *Atelopus* species. We compare with some similar species and other species with relatively close geographical distribution (in spite of micro-endemism known in the genus). *Atelopus carauta* differs from the new species by adult size is significantly larger, in having *canthus rostralis* and postocular crest yellowish, tubercles on flanks and thighs and belly yellow (Ruiz-Carranza and Hernández-Camacho 1978). *Atelopus chocoensis* differs from the *A. nocturnus* by being larger, having snout more projected, postocular crest more developed, dorsum green-brown, cream yellow flanks with brown spots and belly yellow cream in females (Lötters 1992, Lötters 2005). *Atelopus galactogaster* is different from the new species by larger size, having a slate gray, green-black dor-

sal coloration, smooth flank lacking spiculae and coni, chest and belly immaculate white uniform except for a small black spot on the throat and a brown on the chest (Rivero and Serna 1993). *Atelopus famelicus* is distinguished from *A. nocturnus* by having a more slender body, presence of dorsolateral stripes and absence to spiculae and coni (Rivero and Morales 1995). *Atelopus lynchi* differs from *A. nocturnus* by having less project snout, presence of spots yellowish gray on the *canthus rostralis* and postocular crest, flanks very smooth, and belly bluish gray (Cannatella 1981). *Atelopus quimbaya* is distinguished from the new taxon by having a dorsal surface grey and/or grey greenish with flecks, reticulate or lines brown and eventually yellow spots, a less projected snout, inconspicuous vertebral neural processes, a dark brown venter with yellows marks (Ruiz-Carranza and Osorno-Muñoz 1994). *Atelopus monohernandezii* differs from *A. nocturnus* by having smooth dorsal surfaces on the head and body, presenting big warts in the flank surfaces and a brown-reddish venter color (Ardila-Robayo *et al.* 2002). *Atelopus nicefori* is distinguished from the new species by having a less developed postocular crest, green-yellowish flanks, a dark green or pink-brown dorsum, venter yellow-orange with brown markings on the throat and a green-yellowish palm hand and plantar foot (Rivero 1963). *Atelopus sanjosei* is distinguished from the new taxon by a less projected snout, a smooth dorsal surface, green dorsum with brown marks in reticulate form and a white or yellow venter occasionally with a few small brown blotches (Rivero and Serna 1989). *Atelopus sernai* differs from *A. nocturnus* in having a shorter snout, inconspicuous vertebral neural processes, a brown dorsum with bright green blotches and plantar hand, palmar foot, arm, and thigh surfaces yellowish (Ruiz-Carranza and Osorno-Muñoz 1994). *Atelopus simulatus* differs from the new species by having inconspicuous vertebral neural processes, smooth dorsal head surface, dorsum reticulate green and venter yellowish green with brown blotches (Ruiz-Carranza and Osorno-Muñoz 1994). *Atelopus sonsonensis* differs from the new taxon by having a shorter snout, a blue-green with brown reticulate flanks in males, tibio-fibula length relatively longer and a cloacal opening at midlevel of the thighs (Vélez-Rodríguez and Ruiz-Carranza 1997).

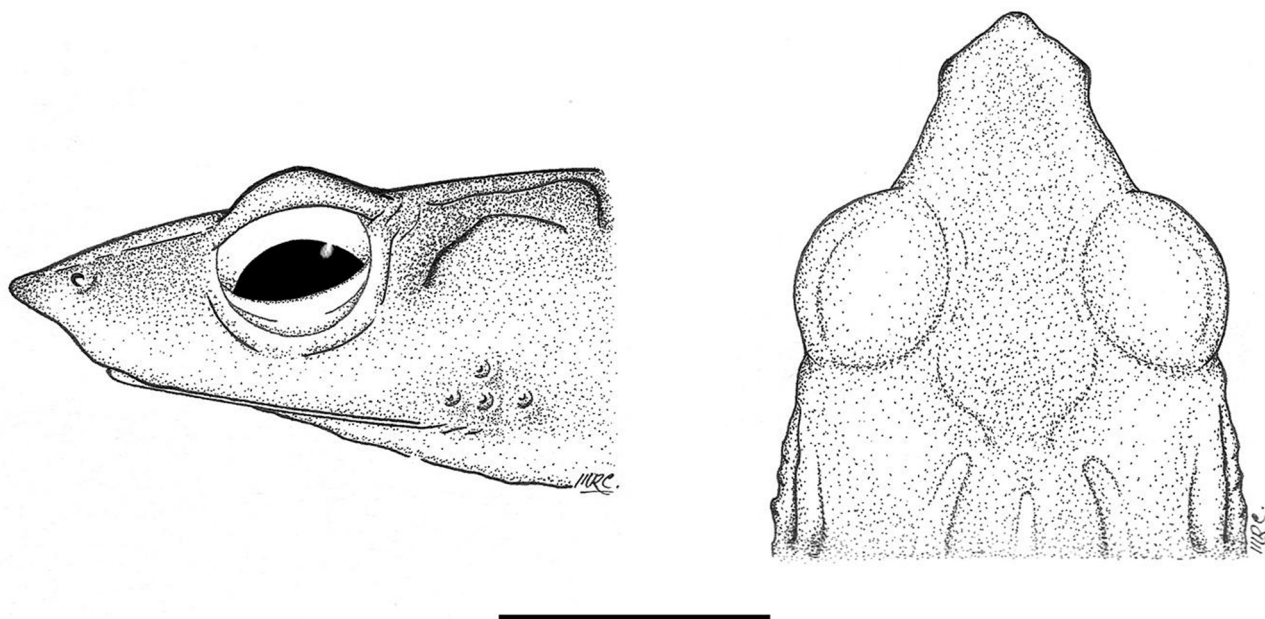


FIGURE 2. Lateral (left) and dorsal (right) aspects of the head of *Atelopus nocturnus* **sp. nov.** (MHUA 5280, holotype). Scale bar = 5 mm. Drawings by M. Rivera-Correa.

Description of holotype. Head longer than wide, head width less than one third SVL ($HDWD/SVL = 0.28$); snout acuminate in dorsal view, slightly depressed; in lateral view, profile of tip of snout to the anterior margin of jaw curved and remarkably protuberant (Fig. 1); nostrils slightly protuberant, directed laterally, situated at posterior of apex of lower jaw; *canthus rostralis* distinct, slightly concave from eye to nostril; loreal region concave; lips not flared; interorbital region flat, smooth; eyelid without distinct tubercles; postorbital crest present and conspicuous; tympanic areas covered with warts and coni; tympanic membrane and tympanic annulus absent (Fig. 2); temporal area smooth; choanae small, elliptic, widely separated; vomerine teeth absent; tongue three times longer than wide, broadest posteriorly, free for half its length posteriorly, proximal end of tongue lacking pigmentation. Forearm rel-

atively short ($FAL/SVL = 0.31$); palmar tubercle round; supernumerary palmar tubercles indistinct; thenar and sub-articular tubercles distinct; digital tips with round pads; thumb relatively short ($THBL/HAND = 0.32$), having one phalange; webbing on hands basal, fingers lacking lateral fringes; relative length of fingers $III > IV > II > I$ (Fig. 3). Tibia relatively short ($TIBL/SVL = 0.42$); fold on distal half of inner edge of tarsus present; inner metatarsal tubercle oval; outer metatarsal tubercle round, raised, about two thirds length of inner metatarsal tubercle; supernumerary plantar tubercles inconspicuous and subarticular tubercles conspicuous; digital pads distinct; webbing formula of foot $I\ 0 - 0^+ II\ 0 - 1^{1/2} III\ 0 - 3 IV\ 3 - 0 V$; relative length of toes $IV > V > III > II > I$. Lateral postocular surfaces bearing numerous warts with coni; undersides of arms tubercled; dorsal surfaces smooth with conspicuous vertebral neural processes and scattered warts and spiculae increasing in number toward arms and anterior and proximal upper surfaces of forelimbs, bearing numerous spiculae evenly distributed; throat, chest, belly, undersides of hind limbs smooth and free of warts; cloacae opens as an inconspicuous tube above the thighs, directed posteriorly; warts present lateral to cloacal opening.

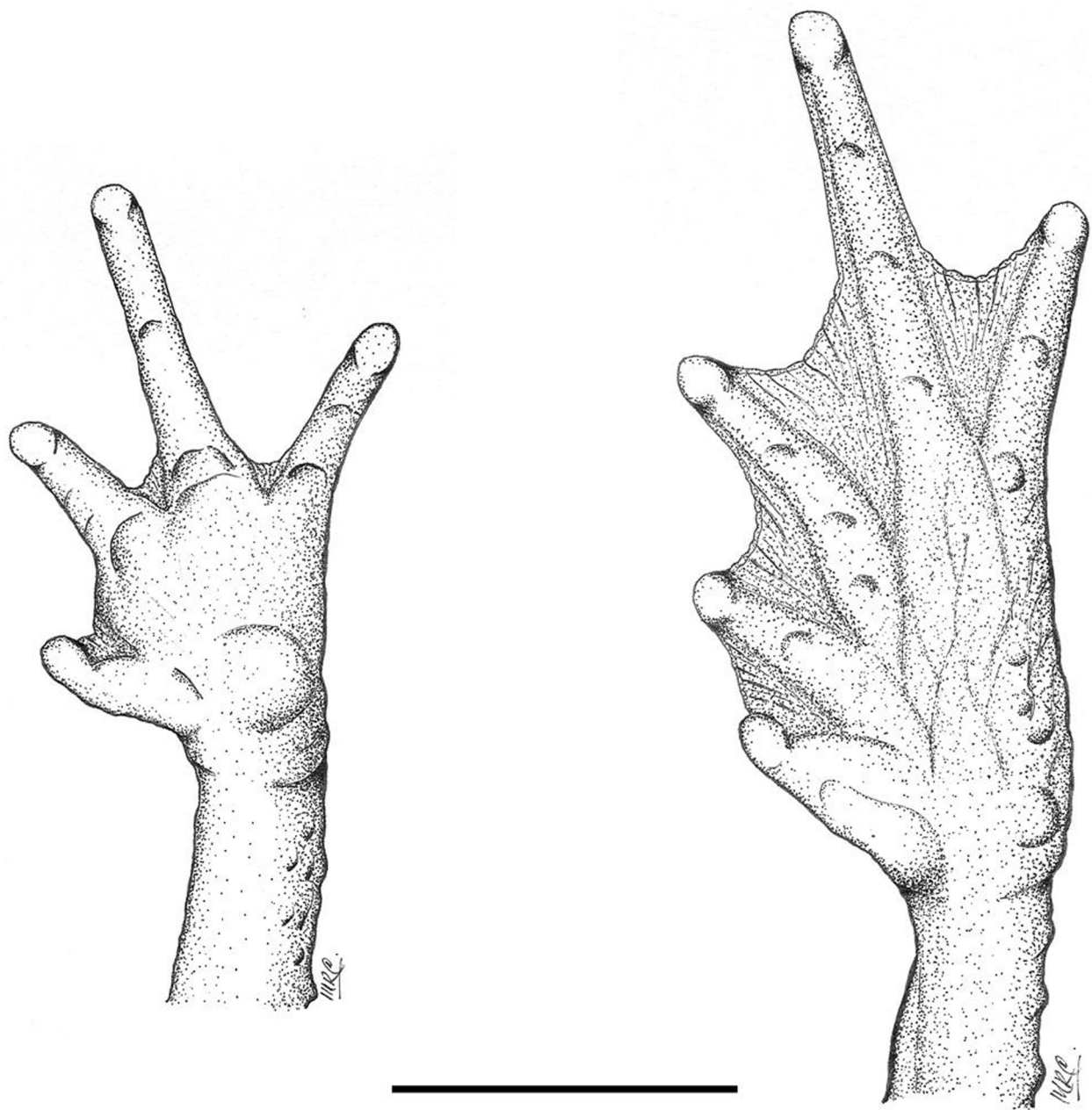


FIGURE 3. Hand (left) and foot (right) of *Atelopus nocturnus* **sp. nov.** (MHUA 5280, holotype). Scale bar = 5 mm. Drawings by M. Rivera-Correa.

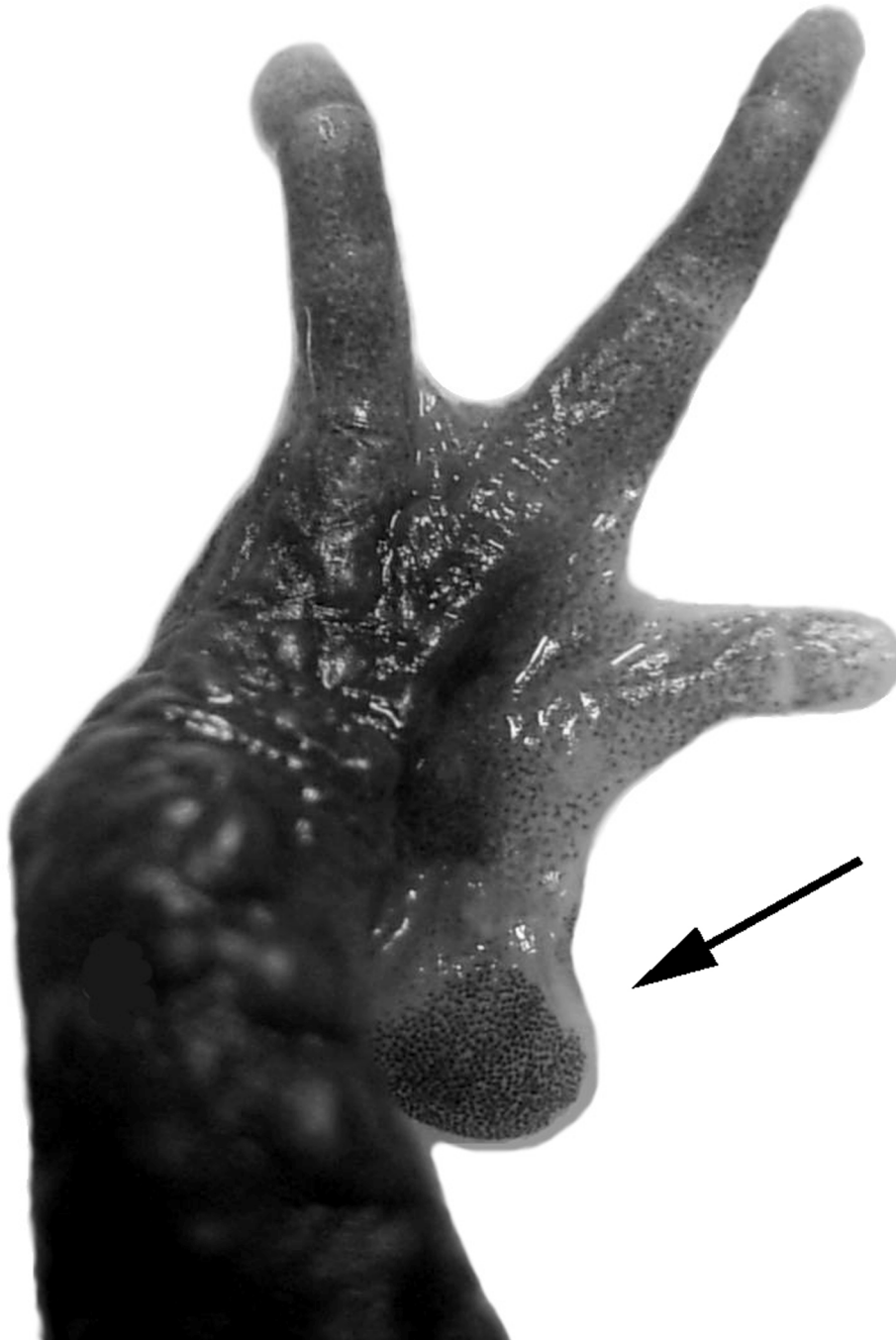


FIGURE 4. Arrow indicating nuptial excrescences (keratinous spines) on Finger I of the hand of an adult male *Atelopus nocturnus* **sp. nov.** (MHUA 5283, paratopotype). Photograph by M. Rivera-Correa.

Coloration in life. Dorsal surface of head and body dark reddish brown, upper surface of flanks brown to orange; warts with conical cream; throat, chest, belly, and ventral surfaces of limbs bright orange; fingers I and toes I and II pale yellow; palmar hand and plantar foot dark orange. Iris, bright yellow with spots brown and fine black reticulations.

Coloration in preservative. Dorsum dark brown; flank surfaces, dorsal surfaces of fingers I and toes I and II cream, tips of digits of hand and foot cream dorsally; throat, venter, palmar and plantar surfaces uniform cream, outer metatarsal tubercle cream.

Measurements of holotype. SVL: 33.0, HLQS: 11.9, HDWD: 9.1, SW: 8.4, IOED: 8.5, IOID: 3.1, EYDM: 3.8, EYNO: 2.6, ITND: 3.1, NSD: 2.5, HAND: 8.3, THBL: 2.8, FAL: 10.1, FL: 14.4, TIBL: 13.8, FOOT: 12.6

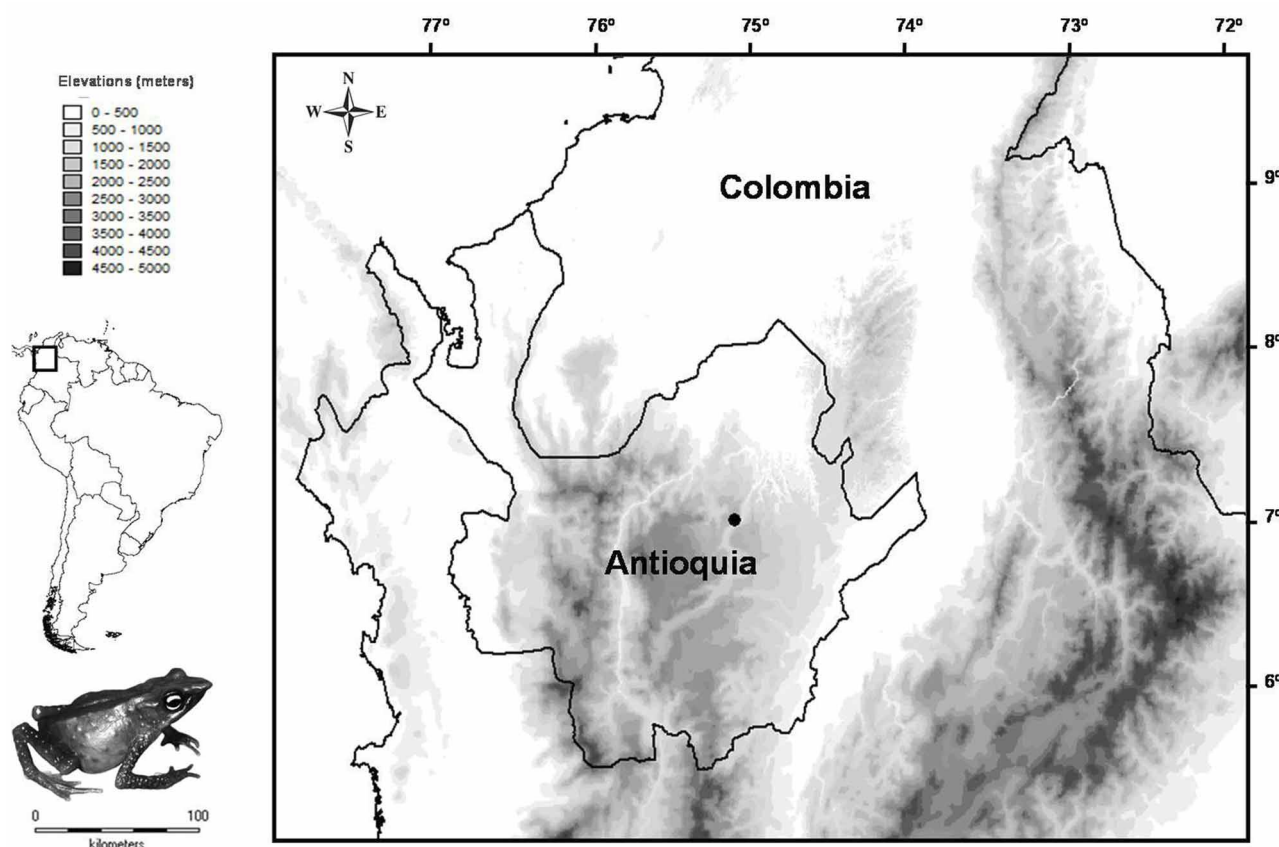


FIGURE 5. Distributional map of *Atelopus nocturnus* sp. nov. in Colombia. Solid circles indicate type localities and the unique distribution current known for the new species.

Variation. Morphometric variation is described in Table 1. Females are larger than males; the forearm of males is swollen; and nuptial pads are evident covering dorsum of finger I in males (Fig. 4). One female (MHUA 5279) differs in having more numerous warts on the dorsum of the body and the flanks; another female (MHUA 5285) presents more warts with coni in the postocular region. In two males (MHUA 5281, 5283), the snouts are acuminate in dorsal view and the tops are sloped anteroventrally in lateral view. In life, dorsal color vary from uniform pale brown (MHUA 5284, male) to reddish brown (MHUA 5285, female); females are bright orange ventrally, whereas in males it varies from white to yellowish cream and has marks and irregular dark brown stripes (Fig. 6); palmar hand and plantar foot dark orange in females and light orange in males.

Etymology. The specific name comes from the Latin adjective *nocturnus* (of the night), in reference to the nocturnal activity of this species, an unusual and previously unknown behavior in other species of the genus *Atelopus*.

Geographic distribution and natural history. The new species is known only from the type locality in the northern Cordillera Central, Municipio de Anorí, Departamento de Antioquia, Colombia, ca.1670 meters above sea level. (Fig. 5). The habitat of *A. nocturnus* is composed of remnant secondary very humid pre-montane forest with a high abundance of arboreal ferns, bromeliads and other epiphytes. The annual mean temperature varies from 18 to 24 °C, with 4000 to 8000 mm of annual precipitation (Gutiérrez-Cardenas 2002). All specimens were collected during unusual dry season (In the area the wet season occurs in May-October and November-April, however, the rains fall in July decreasing significantly). The individuals were found sitting on leaves of shrubs and ferns at a maximum height of one meter near a stream and active during night, except for an individual (MHUA 2472) was found by day while sleeping. The adult females had convoluted oviducts and small white ova, males possessed nuptial excrescences and one pair was found in amplexus (MHUA 5284 and MHUA 5285; Fig. 7), suggesting reproductive activity in dry season. Four additional juveniles were observed and not collected. Calling behavior and tadpole are currently unknown. *Atelopus nocturnus* was found sympatric with the following other anurans: *Rheobates palmatus*, *Pristimantis penelopus*, *Centrolene antioquiense*, *C. savagei*, *Espadarana* sp.

TABLE 1. Variation in measurements (in mm) of the type series of *Atelopus nocturnus* **sp. nov.** See text for abbreviations.

Measurement (mm)	Females (n=3)				Males (n=6)			
	Mean	SD	Max.	Min.	Mean	SD	Max.	Min.
SVL	33.8	0.70	34.3	33.0	23.4	1.69	25.0	20.2
HLQS	11.5	0.48	12.0	11.0	9.1	0.74	10.0	8.1
HDWD	8.6	0.50	9.2	8.2	6.5	0.17	6.7	6.3
SW	8.1	0.25	8.4	8.0	6.6	0.32	7.0	6.1
IOED	8.2	0.55	8.6	7.8	6.5	0.29	6.8	6.0
IOID	3.1	0.15	3.3	3.0	2.5	0.20	2.8	2.2
EYDMD	3.2	0.52	3.8	2.8	2.5	0.20	2.8	2.4
EYNO	2.7	0.06	2.8	2.7	2.1	0.21	2.5	1.9
ITND	3.0	0.23	3.1	2.7	2.2	0.15	2.5	2.1
NSD	2.1	0.45	2.5	1.6	1.7	0.25	2.0	1.3
HAND	7.9	0.42	8.3	7.5	5.5	0.38	5.9	5.0
THBL	2.4	0.35	2.8	2.2	1.8	0.12	2.0	1.7
FAL	10.0	0.65	10.6	9.3	7.2	0.83	8.3	6.2
FL	14.4	0.09	14.4	14.3	10.1	0.51	11.0	9.6
TIBL	13.6	0.17	13.8	13.5	9.8	0.70	10.7	8.7
FOOT	12.6	0.62	13.2	11.9	8.9	0.62	9.6	7.8



FIGURE 6. Ventral color pattern variation of male *Atelopus nocturnus* **sp. nov.** Left to right: MHUA 2472 (SVL = 25.0 mm), MHUA 5281 (SVL = 22.5 mm), MHUA 5282 (SVL = 24.1 mm), MHUA 5283 (SVL = 20.1 mm), MHUA 5284 (SVL = 23.4 mm), MHUA 5286 (SVL = 24.2 mm). Photograph by M. Rivera-Correa.



FIGURE 7. Amplexus in *Atelopus nocturnus* **sp. nov.** (MHUA 5284, adult male paratopotype, SVL = 23.8; MHUA 5285 adult female paratopotype, SVL = 34.3 mm). Photograph by L. Bravo-Valencia.

Remarks. Knowledge of the alpha-level taxonomy of *Atelopus* continues to increase with new species descriptions, additionally to new taxa potentially estimated (e.g. Lötters *et al.* 2002; Barrio-Sanz and Venegas 2005; Acosta-Galvis *et al.* 2006, Coloma *et al.* 2007, Lehr *et al.* 2008, Venegas *et al.* 2008). However, efforts to understand phylogenetic relationships among harlequin frogs remain little known, because they have been poorly explored (Coloma *et al.* 2002, 2007), in spite of some molecular approaches (e.g. Noonan and Gaucher 2005, Guayasamin *et al.* 2010, Lötters *et al.* 2010, 2011). Several authors have suggested that it is premature to recognize species groups in the genus *Atelopus* (Vélez-Rodríguez and Ruiz-Carranza 1997; Coloma *et al.* 2002, 2007; Lötters *et al.* 2002) because of intra-individual and intraspecific variation detected in the lack of a terminal phalanx on the thumb, which defines it. Recently, Lötters *et al.* (2011) demonstrated that the proposed species groups based on frog-like versus toad-like overall appearance (i.e. *longirostris* and *ignescens* groups) or phalangeal reduction in the thumb (i.e. *flavescens* group) are not monophyletic, thus characters used to define them are not recovered as synapomorphies. For that reason, we prefer not to assign *A. nocturnus* to any particular phenetic group, until this species is included in a rigorous phylogenetic analysis.

Following the IUCN Red List categories and criteria (IUCN 2001), *A. nocturnus* should be categorized as Data Deficient (DD), because of the lack of studies on demography, genetic structure, or reproductive behavior. However, we believe that given the critical situation facing the genus (i.e. 62 species of the Andean *Atelopus* are Critically Endangered or possibly extinct, Stuart *et al.* 2008), it is necessary to have some estimate of the conservation status of all Colombian species. *Atelopus nocturnus* currently is known only from a range of less than 10 km², and a dozen individuals (in exhaustive searches for more than five years). Additionally, several threats are acting (e.g. habitat fragmentation and inundation by the Porce III-IV basin hydroelectric project near to the type locality) Thus, we recommend placing *A. nocturnus* in the category Critically Endangered (CR). We advocate urgent field surveys

(including scientific collections of the larval, adults and tissues samples), for assessment of the unsolved taxonomic status of many species, and studies of risk to external harmful agents (i.e. assess presence of *Batrachochytrium dendrobatidis*). Given this, it helps to refining the information on the conservation status of the harlequin frogs in the Andean region, and be possible to establish adequate conservation measures. With the aim of this species is recognized by the local community, we tentatively propose the common name *sapo arlequín nocturno* (nocturnal harlequin toad). We hope that contributions like this will motivate the government, environmental NGO's, owners of private nature reserves, to facilitate biodiversity studies and to reveal the real amphibian's richness of Colombia.

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Appendix 1. Additional specimens examined

Atelopus mono-hernandezi: COLOMBIA: Departamento de Santander: Charal, Virolín, Hacienda La Argentina, 2200 m (ICN 05422-22, 05427-28, 05989-90, 05999-06002). *A. nicefori*: COLOMBIA: Departamento de Antioquia: Municipio de Urroa, Vereda El Chuscal (ICN 03484-85). *A. sanjosei*: COLOMBIA: Departamento de Antioquia: Municipio de Amalfi, El Jardín, 700 m (MHUA 0255-56). *A. sernai*: COLOMBIA: Departamento de Antioquia: Municipio de Bello, Serranía de las Baldías, Km 5-8 carretera San Félix – Boquerón, 620'N , 75 35'W (ICN 04120, 04162, 04242-43, 09868-71, Paratypes); Municipio de Belmira, El Morrón, 2800 m (MHUA 0482-83, 0911-913, 0924-25, 1050, 1092-93, 1514); Páramo de Belmira, 2900 m (MHUA 1023-25); Quebradona 2900 m (MHUA 1022). *A. sonsonesis*: COLOMBIA: Departamento de Antioquia: Municipio de Sonsón: Cauzal casi 15 Kms SE Argelia, 1500 m (ICN 37517-30, Paratypes).