

Two new harlequin frogs (*Anura: Atelopus*) from the Andes of northern Peru

PABLO J. VENEGAS, ALESSANDRO CATENAZZI, KAREN SIU-TING & JORGE CARRILLO

Abstract. Two new species of *Atelopus* (harlequin frogs) are described from the Andes of northern Peru, one from the northern Cordillera de Huancabamba (Departamento de Piura), 2,950 m elevation, and the other from an inter-Andean valley of the upper Marañon basin, Cordillera Central (Departamento de La Libertad), 2,620 m elevation. We also suggest the possible link between infection by the chytrid fungus and mortality of harlequin frogs in the upper Marañon basin in 1999.

Key words. Bufonidae, *Atelopus patazensis* sp. n., *A. eusebiodiazi* sp. n., *Batrachochytrium dendrobatidis*, Marañon basin, Cordillera de Huancabamba, Peru.

Introduction

With more than 100 species *Atelopus* DUMÉRIL & BIBRON, 1841 constitutes the most species-rich genus of Bufonidae in the Neotropics (LA MARCA et al. 2005). Most *Atelopus* species occur in montane habitats above 1,500 m elevation and have relatively restricted distributions (e.g. LÖTTERS 1996). *Atelopus* appears to belong to be one of the most threatened amphibian genera worldwide, since populations of most of its species have dramatically declined over the past two decades, even in sites little affected by anthropogenic alteration (LA MARCA et al. 2005). Life history traits, dependence on montane stream habitats and the restricted distributions of *Atelopus* species seem to contribute to the vulnerability of these amphibians. LA MARCA et al. (2005) reported that up to 75% of the species in the genus with distributions restricted to elevations over 1,000 m have disappeared. Chytridiomycosis, a fungal infection caused by *Batrachochytrium dendrobatidis* (*Bd*), has been associated with declining populations in at least nine species of Central and South American *Atelopus* (LA MARCA et al. 2005). POUNDS et al. (2006) suggested a link of *Bd* infection and climate change as the cause for declination of Andean frog popu-

lations while LIPS et al. (2008) rejected this hypothesis, suggesting that the loss of amphibians in Central and South America are best explained by *Bd* spreading through upland populations.

Atelopus currently includes 13 nominally described species in Peru, one third of which has been described in the last five years (LÖTTERS & HENZL 2000, LÖTTERS et al. 2002a, b, 2005a, LÖTTERS 2003, 2007, VENEGAS & BARRIO 2005, COLOMA et al. 2007). One of the main reasons for the recent increase in the number of known species is collecting from unexplored areas throughout the Andes (e.g. Rapid Biological Inventories, LEHR 2002). At least 17 additional forms of Peruvian *Atelopus* remain to be described, including those that probably represent new taxa (LÖTTERS et al. 2005b). Most *Atelopus* species have relatively small distribution ranges with many species only known from a single population confined to one stream system (LÖTTERS 1996). Population declines have already been reported for *Atelopus* species in northeastern Peru (see LIPS et al 2008). *Bd* is suspected to be affecting the populations of *Atelopus* species in this country, but its occurrence – in relation to time and space – remains largely unexplored (LA MARCA et al. 2005, LÖTTERS et al. 2005b).

The purpose of this paper is to describe two new species of *Atelopus*, one from the northern portion of the Cordillera of Huancabamba and the other from the northern portion of the Cordillera Central in the upper Marañón basin. We also document the earliest known record of *Bd* in *Atelopus* in the northern Andes of Peru.

Materials and methods

We followed the format of COLOMA et al. (2000) along with some diagnostic characters of LÖTTERS et al. (2005a). We describe the webbing formulae using the system of SAVAGE & HEYER (1969), as modified by MYERS & DUELLMAN (1982) and SAVAGE & HEYER (1997). Sex was determined through external sexually dimorphic characters typical in the genus (e.g. LÖTTERS 1996). Morphometric data to the nearest 0.1 mm were taken with dial callipers, following the character definitions of GRAY & CANNATELLA (1985), except for length of flexed forearm and sacrum width (see COLOMA et al. 2000). Abbreviations of measurements used are: snout vent length (SVL); tibia length (TIBL); foot length (FOOT); head length from the squamosal (HLSQ); head length from the exoccipital (HLEX); interorbital distance (IOD); head width (HDWD); eye diameter (EYDM); eye to nostril distance (EYNO); internarial distance (ITNA); length of flexed forearm (RDUL); hand length (HAND); thumb length (THBL) and sacrum width (SW).

Data on other *Atelopus* species were taken from literature sources (as mentioned throughout text) and examination of preserved material at Museo de Historia Natural de la Universidad Nacional Mayor de San Marcos (MUSM), Lima.

We used histological preparations to study the infection with *Bd* in skin tissues of one of the new species described. Skin samples were examined from specimens that had been fixed in 10% formalin after collection in the field, and have been stored in 70% etha-

nol. We studied four individuals collected in 1993 (MUSM 15893-15896) and three collected in 1999 (MUSM 21183-21185), all from the type locality. Skin samples measured approximately 5 × 10 mm and were obtained from vertical sections in the inner part of thighs and from longitudinal sections in the toes to maximize the length of stratum corneum in the sample. We examined at least three replicates of thigh sections and three replicates of toe section for each individual. All skin samples were dehydrated, cleared, embedded in paraffin, cut into 5 µm thick sections and stained with Hematoxylin and Eosin and PAS (Periodic Acid Schiff), thus following the procedure described by DRUNY & WALLINGTON (1980). We examined samples at 400X and 1000X and categorized them as negative when we could not find any structure of *Bd*, and positive when we encountered zoospores or other structures of the fungus (see L. BERGER, R. SPEARE & A. KENT: Diagnosis of chytridiomycosis in amphibians by histologic examination: <http://www.jcu.edu.au/school/phtm/PHTM/frogs/histo/chhisto.htm> – latest access: 20 November 1999).

Atelopus eusebiodiazi sp. n.

(Figs. 1-4)

Atelopus sp. 18: VENEGAS & CISNEROS 2005: 154.

Holotype: MUSM 7138, an adult female from Huamba, 22 km ESE (airline) of Ayabaca (4°43'7.2" S, 79°31'50.88" W) at elevation 2,950 m, near Cerro Mayordomo, Provincia de Ayabaca, Departamento de Piura, Peru, obtained by EUSEBIO DIAZ between 19 and 25 September 1987.

Paratopotypes: MUSM 7133, 7135-7137, adult males, MUSM 7134, 7141, 7139 adult females.

Diagnosis: (1) Large-sized *Atelopus* (SVL males 35.9-41.0 mm, \bar{x} = 38.3, n = 5; females 43.4-47.4 mm, \bar{x} = 41.4, n = 3); (2) hind lim-

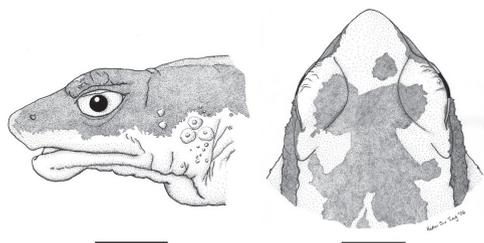


Fig. 1. Lateral and dorsal views of holotype of *Atelopus eusebiodiazi*. Bars equal 5 mm.

bs short, tibiotarsal articulation reaching at least to temporal crest when leg adressed forward along body (TIBL/SV L = 0.31-0.37, n = 8); FOOT > TIBL; (3) phalangeal formula of hand 2-2-3-3 (determined by external examination), finger webbing absent; (4) foot webbing formula I (o)-(o) II (o)-(o to o+) III (o to 1-)-(o+ to 2-) IV (o+ to 2-)-(o to o+) V; (5) head longer than wide; snout acuminate with blunt point in dorsal view, protruding beyond lower jaw; (6) tympanic membrane and tympanic annulus absent; (7) dorsal surface of body bearing few warts and scattered coni, more dense on the posterior half of dorsum and dorsal surface of thighs; (8) yellow or cream coni (in preservative) and some spiculae in the postorbital region, flanks, and dorsolateral region; (9) vertebral neural processes inconspicuous; (10) in preservative, dorsal surface black or dark brown with yellow or cream irregular marks and with an irregular cream or yellow stripe that extends dorsolaterally from the tip of the snout to the groin; flanks black; (11) venter yellowish cream with 1 or 3 small black blotches in the gular region and blotches on palms and soles; (12) gular region with coni.

Based on the combination of these characters, *A. eusebiodiazi* can be distinguished from all described *Atelopus* species. Several harlequin frogs from Ecuador and Colombia share with *A. eusebiodiazi* an acuminate snout with blunt point in dorsal view and protruding beyond lower jaw and/or dark dorsal coloration (black or brown) with clear venter (yellow or cream): *Atelopus chocoensis* LÖTTERS, 1992, *A. famelicus* RIVERO & MORALES,

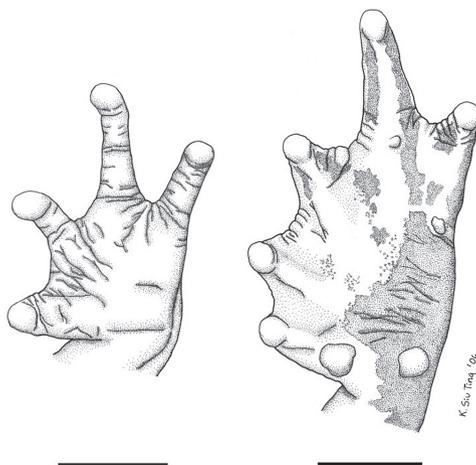


Fig. 2. Palm and sole of holotype of *Atelopus eusebiodiazi*. Bars equal 5 mm.

1992 (including its junior synonym *A. negreti* RUIZ-CARRANZA, VÉLEZ-RODRIGUEZ & ARDILA-ROBAYO, 1995), *A. galactogaster* RIVERO & SERNA, 1991, *A. longirostris* COPE, 1868, *A. lynchi* CANNATELLA, 1981, *A. nicefori* RIVERO, 1963, *A. petersi* COLOMA, LÖTTERS, DUELLMAN & MIRANDA-LEIVA, 2007 and *A. subornatus* WERNER, 1899. *Atelopus chocoensis* can be distinguished by having a prominent supratympanic crest and a more elongate snout (LÖTTERS 1992); *A. famelicus* differs by having with numerous black dots on the venter (CASTRO & BOLIVAR 2005: 76); *A. galactogaster* is distinguished by lacking spiculae and coni on flanks and by exhibiting white ventral coloration (RIVERO & SERNA 1991); *A. longirostris* and *A. lynchi* differ by possessing a more protruding snout, a slender body and different ventral coloration in life, i.e. white in *A. longirostris* and bluish gray in *A. lynchi* (PETERS 1973, CANNATELLA 1981); *A. nicefori* can be distinguished through its more protruding snout, slender body and smaller size (RIVERO 1963); *A. petersi* is distinct because of the presence of cream spiculae on forearms, flanks and dorsal surface of thighs and by lacking coni in the gular region (COLOMA et al. 2007); *A. subornatus* differs by lacking coni and spiculae on the flanks and through



Fig. 3. Dorsal and ventral views of holotype of *Atelopus eusebiodiazi*.



Fig. 4. Dorsal and ventral views of male paratype MUSM 7135 of *Atelopus eusebiodiazi*.

smaller size (LÖTTERS 1996). Other Peruvian *Atelopus* species with similar characters such as having an acuminate snout and/or dark dorsal coloration include *A. erythropus* BOULENGER, 1903, *A. pachydermus* O. SCHMIDT, 1857, *A. peruensis* GRAY & CANNATELLA, 1985, *A. seminiiferus* COPE, 1874, *A. tricolor* BOULENGER, 1902 and the new species described below. *Atelopus erythropus* differs from *A. eusebiodiazi* by having a slender body, an almost entirely smooth skin and by its smaller size (LÖTTERS 2003); *A. pachydermus* is distinct by having a tan to yellow venter with light to dark brown blotches and larger size (COLOMA et al. 2007); *A. peruensis* differs by having a green dorsum and flanks with white spiculae (GRAY & CANNATELLA 1985); *A. seminiiferus* differs by possessing a black dorsal coloration with scattered white spots and pink venter with black flecks (LÖTTERS & SCHULTE 2005); *A. tricolor* can be distinguished by having red palms and soles and a slender body (LÖTTERS & DE LA RIVA 1998). *Atelopus eusebiodiazi* differs from the new species described below by having an acuminate snout in dorsal view and yellow venter as opposed to a truncate snout and orange venter.

Description of holotype: body robust; no neural spines externally visible; head longer than wide; head length less than one third of SVL (HLSQ/SVL 0.297, HDWD/SVL 0.253); snout acuminate with blunt tip from above, protruding beyond lower jaw in dorsal and lateral views, dorsally slightly depressed (Fig. 1); nostril blunt, slightly protuberant, curved laterally, situated anterior to mandibular symphysis; canthus rostralis distinct, straight from palpebrum to tip of snout, weakly flared, concave from eye to nostril; EYNO longer than EYDM (EYNO/EYDM 1.090); loreal region concave; lips slightly flared; interorbital region and occiput flat; palpebrum not flared; postorbital crest distinct, not glandular; postorbital area covered with conical and some scattered spiculae; tympanic membrane and tympanic annulus (and thus expectably columella) absent; choanae rounded, widely separated; tongue about two or three times as long as wide; broadest anteriorly, free for two thirds of its length.

Forearm relative short, less than one third of SVL (RDUL/SVL 0.191); palmar tubercle indistinct; thenar tubercle absent; rest of palm weakly wrinkled without defined sub-articular tubercles at any joints of fingers; tips of digits with rounded pads (not expanded) and no circum-marginal groove; thumb apparently with two phalanges, relatively short (THBL/HAND 0.355); hand webbing and lateral fringes on fingers absent; relative length of fingers: $I < II < IV < III$.

Tibia relatively short, less than half SVL (TIBL/SVL 0.320); tibiotarsal articulation reaching at least to temporal crest, when hind limb is adpressed forward along body; tarsal fold absent; foot larger than tibia (TIBL/FOOT 0.894); inner metacarpal tubercle indistinct; outer metatarsal tubercle ill defined, not elevated, rounded; rest of sole flared, weakly wrinkled with indistinct sub-articular tubercles including joints of phalanges of toes II-V; foot webbing formula I (o)-(o) II (o)-(o+) III (o+)-(2-) IV (1+)-(o) V; relative length of toes: $I < II < III < V < IV$.

Dorsal surface smooth except for scattered conical from sacral to cloacal region; tym-

panic region with dense coni and scattered spiculae; dense coni and some spiculae on entire flank and in dorsolateral region; dorsal surface of forearm with coni in the proximal portion; dorsal surface of in the thigh with coni; ventral surface wrinkled; gular region wrinkled distally.

In preservative, dorsal surface of body, flanks and limbs chocolate brown with irregular black blotches and some yellowish cream blotches on flanks; ventral surface cream including palm and sole with irregu-

lar small black blotches on sole. Coloration in life is unknown.

Measurements of holotype (in mm): SVL 47.4, HDWD 12.0, HLSQ 14.1, HLEX 12.6, EYDM 3.3, IOD 3.3, ITNA 3.6, EYNO 3.6, TIBL 15.2, FOOT 17.0, RDUL 9.1, HAND 10.7, THBL 3.8, SW 13.2.

Variation: meristic variation of the type series (four females and four males) is given in Table 1. Two individuals (MUSM 7133, 7136) resemble the holotype in preservative coloration.

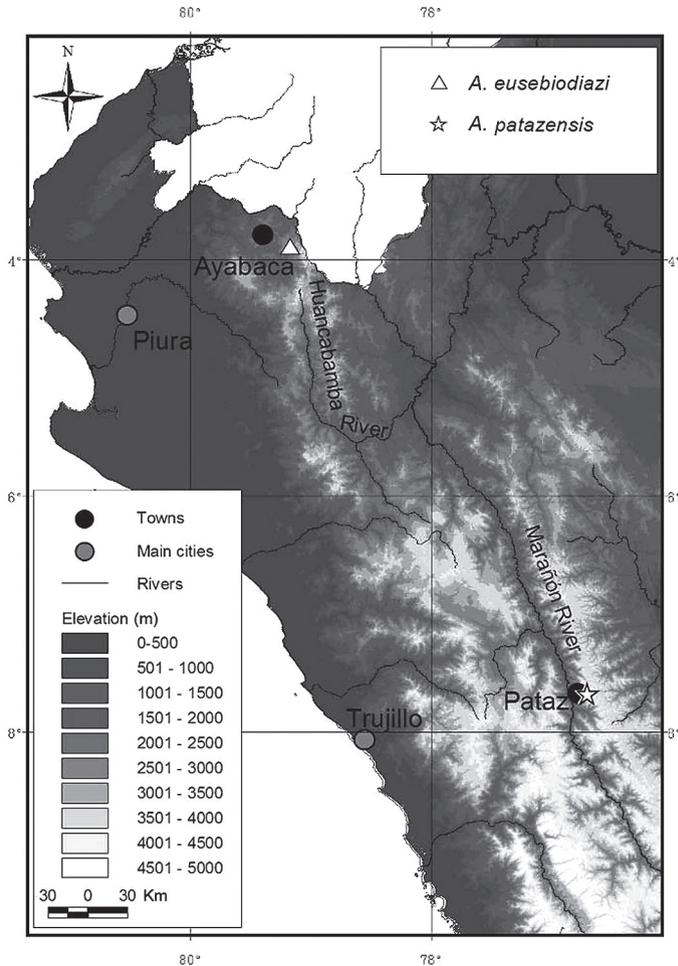


Fig. 5. Map of northern Peru showing the known distributions of *Atelopus eusebiodiazi* and *Atelopus patazensis*.

tion, whereas the other paratopotypes have a black dorsum with some irregular yellowish cream marks and a yellowish cream irregular dorsolateral stripe that extends from the tip of the snout to the groin. The ventral coloration of all paratopotypes is similar to that of the holotype, although three individuals (MUSM 7137, 7139, 7134) have one or

Tab. 1. Measurement (in mm) and proportions of type series of *Atelopus eusebiodiazi* and *A. patazensis*. Mean followed by range in parentheses.

	<i>A. eusebiodiazi</i>		<i>A. patazensis</i>	
	males (n = 5)	females (n = 6)	males (n = 6)	females (n = 4)
SVL	38.3 (35.9-41.0)	41.4 (33.4-47.4)	37.6 (34.8-39.8)	46.7 (42.7-48.8)
TIBL	13.9 (13.6-14.6)	13.7 (12.4-15.2)	14.1 (10.9-15.5)	15.9 (15.8-16.2)
FOOT	16.0 (14.6-17.5)	15.4 (13.2-17.0)	16.3 (16-17)	19.3 (18.9-20.2)
HLSQ	12.5 (11.8-13.4)	13.2 (11.9-14.1)	11.2 (10.6-11.7)	12.6 (11.5-13.9)
HLEX	11.1 (10.7-12.0)	11.4 (9.9-12.6)	12.2 (11.4-13.1)	13.2 (12.3-13.7)
IOD	3.4 (3.3-3.6)	3.3 (3.3-3.4)	3.9 (3.1-4.4)	4.2 (3.8-4.7)
HDWD	10.5 (10.1-11.0)	10.8 (9.9-12.0)	11.9 (10.9-13.3)	12.6 (11.8-13.3)
EYDM	3.3 (2.9-4.0)	3.4 (3.3-3.6)	3.3 (2.4-3.9)	3.9 (3.7-4.2)
EYNO	2.9 (2.8-3.0)	3.3 (2.7-3.7)	2.7 (2.4-3.2)	3.2 (3.1-3.4)
ITNA	3.5 (3.0-4.2)	3.4 (3.4-3.6)	3.3 (3-3.9)	3.4 (3.2-3.7)
RDUL	8.8 (8.3-9.8)	9.1 (8.5-9.6)	9.5 (8.3-10.5)	12.2 (11.7-12.8)
HAND	9.3 (8.8-10.0)	9.4 (7.9-10.7)	9.6 (8.1-11)	11.3 (10.9-11.7)
THBL	2.8 (2.4-3.1)	3.3 (2.9-3.8)	4.8 (4.3-5.7)	5.9 (5.6-6.1)
SW	11.2 (10.3-12.5)	11.5 (9.7-13.2)	11.2 (10.6-11.6)	13.6 (12.4-14.6)
TIBL/SVL	0.36 (0.34-0.38)	0.337 (0.312-0.371)	0.316 (0.047-0.419)	0.347 (0.329-0.372)
HLSQ/SVL	0.325 (0.315-0.333)	0.323 (0.297-0.353)	0.299 (0.276-0.325)	0.274 (0.251-0.294)
HDWD/SVL	0.274 (0.268-0.281)	0.265 (0.241-0.296)	0.316 (0.273-0.351)	0.274 (0.241-0.292)
RDUL/SVL	0.230 (0.212-0.251)	0.222 (0.191-0.254)	0.251 (0.236-0.269)	0.264 (0.257-0.274)
THBL/HAND	0.295 (0.266-0.318)	0.353 (0.34-0.367)	0.51 (0.4-0.654)	0.522 (0.504-0.539)

two small black blotches in the gular region. Webbing formula varies as follows: I (o)-(o) II (o)-(o to o+) III (o to 1-)-(o+ to 2-) IV (o+ to 2-)-(o to o+).

Sexual dimorphism: in males, the canthus rostralis, palpebrum and postorbital crest are more flared than in females. Males have small warts on flanks, in dorsolateral region and on fore and hind limbs. Females have conical and some small spiculae on the entire flanks and conical on the fore and hind limbs. The gular and pectoral regions in males have more conical than in females and the distal portion of the gular region in females is finely wrinkled. Males present nuptial excrescences covering the entire dorsum of Finger I and a narrow patch covering less than a quarter of the inner part of the dorsal surface of Finger II.

Distribution: *Atelopus eusebiodiazi* is known only from the type locality (Fig. 5), in the northern portion of the Cordillera de Huancabamba, Departamento de Piura, in northwestern Peru, at an elevation of 2,950 m.

Natural history and conservation: *Atelopus eusebiodiazi* inhabits the cloud forest around Cerro Mayordomo. Several individuals were observed in leaf litter and along small streams in September 1987 and some were found again in October 1997 (E. DIAZ, pers. comm.). The cloud forest surrounding Ayabaca and the type locality of *A. eusebiodiazi* is threatened by habitat destruction because of an increase in cattle grazing and agricultural areas. One of us (PJV) visited the type locality and adjacent areas in May and September 2006 but failed to find *A. eusebiodiazi*. The forest on the western slope of Cerro Mayordomo (known as Huamba) is fragmented with patches of less than 100 ha. The largest patch of montane forest near Cerro Mayordomo is found in the neighbouring locality of Anchalá. This isolated forest is known as Bosque de Cuyas (4° 40'S 79°31'W, ca. 800 ha) and is completely surrounded by croplands (FLANAGAN & VELLINGA 2000). In February 2001, PJV surveyed the amphibians of

Bosque de Cuyas without finding a single trace of any harlequin frog. However, another patch of forest on the eastern slope of Cerro Mayordomo, El Toldo or Bosque de Tres Cruces (4°40'S 79°31'W, ca. 700 ha), has not been surveyed so that there is still a chance that *A. eusebiodiazi* can be found here.

Considering the current situation of most Andean *Atelopus* (LA MARCA et al. 2005, LÖTTERS 2007) and the apparent absence of *A. eusebiodiazi* during recent visits, we consider this species to be at least near to extinction (IUCN Red List status: Critically Endangered).

Etymology: The specific name is a patronym for EUSEBIO DIAZ, taxidermist at MUSM, who collected this new species and in recognition of his years of invaluable collaboration in field work and at MUSM.

Atelopus patazensis sp. n.

(Figs. 6-9)

Atelopus pachydermus (non O. SCHMIDT): RODRÍGUEZ et al. 1993: 6 (partim).

Atelopus sp. 12: CATENAZZI & VENEGAS 2005: 148.

Holotype: MUSM 15893, an adult female from Quebrada Los Alisos (7°47'32" S, 77°35'45" W) at elevation 2,620 m, in the vicinity of Patataz, Provincia de Patataz, Departamento de La Libertad, Peru, obtained by FONCHII CHANG in October 1993.

Paratopotypes: MUSM 15894-15896, obtained along with the holotype, MUSM 21183-21185, obtained by A. CATENAZZI and L.O. RODRÍGUEZ on 21 June 1999, MUSM 23108, 7475-7476 (adult males), obtained by P. BALTAZAR and R. TEJADA on 21 August 1990.

Diagnosis: (1) Large-sized *Atelopus* (SVL males 37.8-39.8 mm, \bar{x} = 37.6, n = 6; females 42.7-48.8 mm, \bar{x} = 46.7, n = 4); (2) hind limbs short, tibiotarsal articulation reaching at least to temporal crest when leg adpressed for-

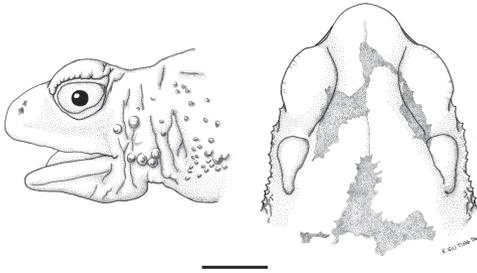


Fig. 6. Lateral and dorsal views of head of holotype of *Atelopus patazensis*. Bar equals 5 mm.

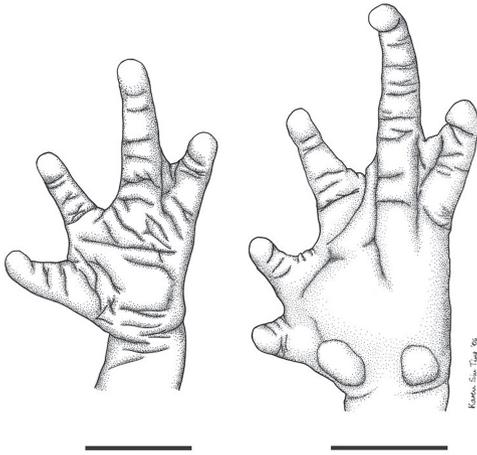


Fig. 7. Palm and sole of holotype of *Atelopus patazensis*. Bars equal 5 mm.

ward along body (TIBL/SVL= 0.329-0.392, n = 10); FOOT > TIBL; (3) phalangeal formula of hand 2-2-3-3 (determined by external examination), finger webbing absent; (4) foot webbing formula I(o)-(o to o+) II (o)-(o to 1+) III (o+ to 1-)-(1 to 2-) IV (1 to 2+)-(o to 1) V; (5) head about as long as wide; snout truncated in dorsal view, slightly protruding beyond lower jaw; (6) tympanic membrane and tympanic annulus absent; (7) dorsal surface of body with warts, in females (only) also with conis; (8) females with conis and spiculae in the postorbital region, dorsolateral region and flanks; males with dorsolateral row of enlarged warts, no spiculae or conis from postorbital region to groin; (9) vertebral neu-



Fig. 8. Dorsolateral view of male individual of *Atelopus patazensis* in life (not a collected individual).



Fig. 9. Diseased female (infected with *Bd*) of *Atelopus patazensis* found in June 1999.

ral processes inconspicuous; (10) in life, dorsal surface orange with a larger black vermiculated or irregular marks including limbs, or dorsum black with orange vermiculated or irregular marks; (11) venter immaculate orange including palm and sole; (12) presence of spiculae below angle of jaws and on posterior throat in males.

Based on the combination of these characters, *A. patazensis* can be distinguished from all described *Atelopus* species. Similar species in northwestern Peru include *A. pachydermus*, *A. peruensis* and *A. eusebiadiazi*. The new species differs from all of them by presenting a truncate snout in dorsal view (versus acuminate in *A. pachydermus* and *A. euse-*

biodiazi, subacuminate in *A. peruensis*; GRAY & CANNATELLA 1985, COLOMA et al. 2007). In addition, *A. patazensis* is smaller than *A. pachydermus* (having male SVL > 51.3mm, female SVL > 55.9 mm) and *A. peruensis* differs from the new species by having in life a green dorsum with white spiculae on flanks (versus orange dorsum with larger black vermiculated or irregular marks or dorsum black with orange vermiculated or irregular marks and absence of white spiculae in *A. patazensis*; GRAY & CANNATELLA 1985, COLOMA et al. 2007). Ecuadorian species which are similar to *A. patazensis* include *A. bomolochos* PETERS, 1973, *A. boulengeri* PERACCA, 1904, *A. exiguus* BOETTGER, 1892, *A. guanujo* COLOMA, 2002, *A. ignescens* (CORNALIA, 1849), *A. onorei* COLOMA, LÖTTERS, DUELLMAN & MIRANDA-LEIVA, 2007 and *A. petersi*. These species share with *A. patazensis* similar dorsal and ventral coloration and/or skin texture. The new species is distinguished from *A. bomolochos* (its conditions given in parentheses; information on coloration referred to, if not mentioned otherwise, is in preservative) by having dorsal warts (usually quite smooth), orange or orange-yellow coloration with large black vermiculated or irregular marks covering dorsal parts including limbs (may be yellowish, yellow-green or light brown) and orange venter (yellow) (PETERS 1973, COLOMA et al. 2007). *Atelopus boulengeri* differs from *A. patazensis* by having smooth skin on the dorsal surfaces and flanks (PETERS 1973). *Atelopus guanujo*, *A. onorei* and *A. petersi* can be distinguished from *A. patazensis* by having an acuminate snout in dorsal view, dorsum uniformly orange or green (in *A. guanujo* and *A. onorei*) and by the presence of whitish spiculae on the forearms, flanks and thighs in the case of *A. guanujo* and *A. petersi* (COLOMA 2002, COLOMA et al. 2007). *Atelopus onorei* is also distinguished by having an aqua blue iris in life which is unique in the genus *Atelopus* (COLOMA et al. 2007). *Atelopus exiguus* is distinct from *A. patazensis* through the presence of white thenar and palmar tubercles, white spiculae on the dor-

sum and smaller size (COLOMA et al. 2000). *Atelopus ignescens* differs from *A. patazensis* by having a completely black dorsum, plus spiculae and coni on the pectoral region (COLOMA et al. 2000).

Description of holotype: body robust; no neural spines externally visible; head about as long as wide; head length less than one third of SVL (HLSQ/SVL 0.288, HDWD/SVL 0.286); snout truncated, protruding beyond lower jaw in dorsal and lateral view, dorsally depressed; nostril oval, not protuberant, curved laterally, situated at level of mandibular symphysis; canthus rostralis distinct, flared, slightly curved from palpebrum to tip of snout, concave from eye to nostril; EYNO about three fourths of EYDM (EYNO/EYDM 0.068); loreal region concave; lips fleshy; interorbital region and occiput flat; palpebrum fleshy; postorbital crest prominent and glandular; postorbital area with small warts; tympanic membrane and tympanic annulus (and thus expectably columella) absent; choanae small, rounded, widely separated; tongue about two or three times as long as wide, broadest anteriorly, free two thirds of its length.

Forearm relatively short, less than one third of SVL (RDUL/SVL 0.260); palmar tubercle well defined, elliptical and rounded; thenar tubercle small, rounded and not well defined; rest of palm wrinkled without defined subarticular tubercle in any joints of fingers; tips of digits with rounded pads (not expanded), on which a circummarginal groove is absent; thumb apparently with two phalanges; relatively short, distance from tip to outer edge of palmar tubercle less than half hand length (THBL/HAND 0.126); webbing in hands absent, finger lacking lateral fringes; relative length of fingers: I<II<IV<III.

Tibia relatively short, less than half SVL (TIBL/SVL 0.348); tibiotarsal articulation extending to near anterior of temporal region, when hind limbs adpressed forward along body; tarsal fold absent; foot larger than tibia; outer metatarsal tubercle triangular and

rounded, inner metatarsal tubercle larger than outer, rounded (distally expanded); rest of sole wrinkled with indistinct subarticular tubercles including joints of phalanges of toes II-V; foot webbing formula is I (o)-(o+) II (o)-(1) III (o+)-(2-) IV (2-)-(o+) V; relative length of toes: $I < II < III < V < IV$.

Dorsal surface with warts and coni, the latter mainly in the scapular region; tympanic region covered by spiculae; dorsolateral region and flanks with coni and spiculae; dorsal surface of forearm and hind limbs with some small warts, scattered coni present on dorsal surface of thigh; ventral surface finely wrinkled without coni or spiculae including in gular region.

In life, dorsal surface of head orange; palpebrum orange with black vermiculation; body orange with extensive black vermiculation on dorsum; dorsolateral region with some small scattered vermiculation; flanks uniformly orange; dorsal surface of limbs with scattered vermiculation; venter, palm and sole uniformly orange; pupil black, surrounded by a dark golden ring. In preservative, orange coloration fades to yellow.

Measurements of holotype (in mm): SVL 46.5, HDWD 13.3, HLSQ 13.4, HLEX 13.7, EYDM 4.0, IOD 3.8, ITNA 3.6, EYNO 3.2, TIBL 16.2, FOOT 20.2, RDUL 12.1, HAND 11.7, THBL 5.9, SW 13.6.

Variation: mensural variation of the type series (six males, four females) is provided in Table 1. Dorsal coloration in *A. patazensis* varies from almost black dorsum and limbs with orange vermiculation or irregular blotches to orange dorsum with black mottling. One female (MUSM 15895) differs from the other type specimens by having some small spiculae in the interorbital space and the posterior surface of palpebrum.

Webbing formulae varies as follows: I (o)-(o to o+) II (o)-(o to 1+) III (o+ to 1-)-(1 to 2-) IV (1 to 2+)-(o to 1) V.

Sexual dimorphism: males develop scattered warts on dorsum without coni or spiculae, a row of enlarged warts in the dorso-

lateral region, postocular region and flanks covered by warts without coni or spiculae, except for forearms and near the arm insertions. Venter is finely wrinkled with spiculae and coni only under the angles of jaws, distal portion of throat and on the ventral surfaces of forearms. Females have spiculae and coni in the tympanic region and dorsolateral region and flanks, as well as coni on the dorsum and dorsal surface of thighs. Males possess nuptial excrescences covering the entire dorsal surface of finger I and about two thirds of the inner part of the dorsal surface of finger II.

Distribution: *Atelopus patazensis* is known only from the type locality (Fig. 5) in an inter-Andean valley of the northern portion of the Cordillera Central in northwestern Peru at an elevation of roughly 2,500-3,000 m. The vegetation at the type locality is dominated by bunchgrass and scattered shrubs.

Natural history and conservation: adult *A. patazensis* were repeatedly observed at the type locality until 1999, when one of us (AC) collected two males and a female along two streams. Two of these harlequin frogs were found dead and the third was still alive at the time of capture (Fig. 9) but died the day after. In addition to these findings, other freshly deceased and currently decomposing bodies of these toads were observed along the streams. On 21 June 1999, AC surveyed the stream Los Alisos which cuts across the town of Pataz and a small affluent of Los Alisos. Three freshly deceased and two dying specimens were recorded after intensive searches along the main stream from 15:30 to 16:00 h. The small stream was located north of the town along the road connecting Pataz with the mining concession of Compañía Minera La Poderosa. Two deceased and one apparently healthy male of *A. patazensis* were observed at this site from 16:15 to 17:00 h. Tadpoles were observed along the main stream of Los Alisos. A dissected gravid female (MUSM 21184; SVL 48.8 mm, mass at capture

9.5 g), found dead on 21 June 1999 at Quebrada Los Alisos, contained 348 eggs of diameter 1.8–2.0 mm ($n = 10$). The eggs were cream in preservative. Surveys on 15 July 2000 along Quebrada Los Alisos and its effluent failed to detect adult *A. patzensis*. Merely a single tadpole was found in a small pool along the main stream channel.

An examination of skin sections of *A. patzensis* revealed that four specimens collected in 1993 were not infected by *Bd*, whereas two of three specimens (MUSM 21183, 21185) collected in 1999 contained *Bd* zoosporengia (Fig. 10). This proves the presence of *Bd* in northern Peru for the year 1999 and may also explain the abrupt population declines in *A. peruensis* and *A. pachydermus* (e.g. LÖTTERS et al. 2005b; COLOMA et al. 2007). These species were abundant during the 1980s and beginning of the 1990s in many localities of the Cajamarca-Celendin and Cutervo ranges respectively, but apparently declined between 1995 and 1998 and have not been observed since 1998 despite increased efforts to find them (PJV, unpubl.).

We lack observations of *A. patzensis* for the time after 1999. However, considering the current situation of most Andean *Atelopus* in general (LA MARCA et al. 2005) and the apparent presence of *Bd* in *A. patzensis*, we consider this species to be at least near to extinction (IUCN Red List status: Critically Endangered).

Etymology: The specific name refers to the type locality.

Taxonomic remarks: According with COLOMA et al. (2000, 2007), the status of *Atelopus bomolochos* has been uncertain, basically because of the concept of *A. ignescens* sensu lato applied by PETERS (1973) and the recognition of an *A. exiguus-bomolochos* complex by GRAY (1983) including several populations of *Atelopus* from southern Ecuador. The recent clarification of the taxonomic status of *A. ignescens* sensu stricto (COLOMA et al. 2000), *A. exiguus* (COLOMA et al. 2000) and *A. pa-*

chydermus (COLOMA et al. 2007) caused the review of the original description and type material of *A. bomolochos* by COLOMA et al. (2000), resulting in the description of a new species, *A. onorei*, based on an Ecuadorian population previously allocated to *A. bomolochos* (e.g. LÖTTERS 1996, COLOMA et al. 2000). With regard to the unclear status of *A. bomolochos*, the characters of *A. patzensis* satisfactorily differentiate these two forms (see the comparison above).

RODRÍGUEZ et al. (1993) reported *A. pachydermus* from the Departamentos de Amazonas, Cajamarca and La Libertad, Peru, based on MUSM collections but without providing reasons for applying this name (at that time applied to material from northern Ecuador; see COLOMA et al. 2007). The record from La Libertad of RODRÍGUEZ et al. (1993) apparently refers to *A. patzensis* since this is the only *Atelopus* from this department at MUSM that was tentatively identified as *A. pachydermus* in the museum catalogue.

Discussion

PETERS (1973) used FOOT > TIBL and relatively long thumbs (with apparently two phalanges) to define a phenetic *Atelopus ignescens* group. Thumb length as used by PETERS (1973) was reviewed by LYNCH (1993), who considered this character as a way of recognizing *Atelopus* species groups and hypothesized that species with phalangeal reduction in the thumb might reflect a monophyletic assemblage (i.e. *flavescens* group sensu LYNCH 1993). *Atelopus eusebiodiazi* and *A. patzensis* share FOOT > TIBL and relatively long thumbs with other species of *Atelopus*. However, we agree with COLOMA et al. (2000, 2007) and COLOMA (2002) that defining *Atelopus* species groups in a phylogenetic sense may be premature. As a result, we cannot state whether similarities shared among Andean *Atelopus* do reflect synapomorphies, plesiomorphies or just convergence.

The majority of Andean *Atelopus* species

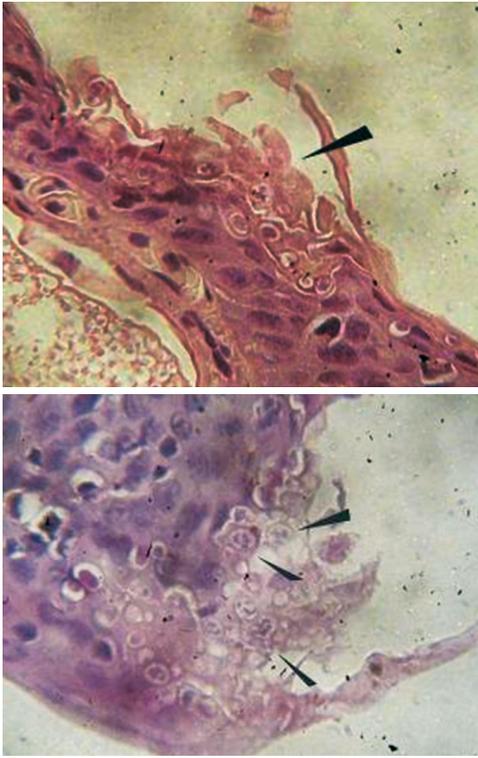


Fig. 10. Above: toe section of *Atelopus patazi* stained with Periodic Acid Schiff (PAS); arrows indicate several zoosporangia of *Bd* in broken layers of the stratum corneum; bottom arrow points to the discharge papillae of a zoosporangium (MUSM 21185, 1000 × magnification). Below: toe section of *A. patazi* stained with PAS; arrow indicates sporangia of *Bd* filled with zoospores among broken layers of the stratum corneum (MUSM 21183, 1000 × magnification).

is “Critically Endangered” when applying IUCN Red List criteria (LÖTTTERS et al. 2004, 2005a, b, LÖTTTERS 2007). We here tentatively suggest both *A. eusebiodiazi* and *A. patazensis* should be placed under the same category. Like LA MARCA et al. (2005) reported for many other Andean *Atelopus*, these two species are likely extinct. As a result, as recently pointed out by LÖTTTERS (2007), there is an urgent need to monitor these and other harlequin frogs and to establish conservation breeding programs.

Acknowledgements

We thank J. CORDOVA and C. AGUILAR for allowing access to the collection of the MUSM. We thank J. CERNAQUÉ (Lab. de Enfermedades Infecciosas, Dep. de Microbiología, Universidad Peruana Cayetano Heredia) and J. SANDOVAL (Lab. de Patología, Hospital Dos de Mayo, Lima) for assistance with histological analysis of skin sections. The 1999 and 2000 field excursions to the Rio Abiseo National Park were kindly organized by APECO (Asociación Peruana para la Conservación de la Naturaleza).

References

- CANNATELLA, D.C. (1981): A new *Atelopus* from Ecuador and Colombia. – *J. Herpetology*, **15**: 133-138.
- CASTRO, F. & W. BOLIVAR (2005): *Atelopus famelicus*. – pp. 76 in RUEDA-ALMONACID, J.V., J.V. RODRÍGUEZ-MAHECHA, S. LÖTTTERS, E. LA MARCA, T. KAHN & A. ANGULO (eds.): *Ranas arlequines*. – Bogotá, Conservación Internacional. Panamericana Formas e Impresos S. A.
- CATENAZZI, A. & P.J. VENEGAS (2005): *Atelopus* sp. 12. – pp. 148 in RUEDA-ALMONACID, J.V., J.V. RODRÍGUEZ-MAHECHA, S. LÖTTTERS, E. LA MARCA, T. KAHN & A. ANGULO (eds.): *Ranas arlequines*. – Bogotá, Conservación Internacional. Panamericana Formas e Impresos S. A.
- COLOMA, L.A. (2002): Two new species of *Atelopus* (Anura: Bufonidae) from Ecuador. – *Herpetologica*, **58**: 229-252.
- COLOMA, L.A., S. LÖTTTERS & A.W. SALAS (2000): Systematics of the *Atelopus ignescens* complex (Anura: Bufonidae): designation of a neotype of *Atelopus ignescens* and recognition of *Atelopus exiguus*. – *Herpetologica*, **56**: 303-324.
- COLOMA, L.A., S. LÖTTTERS, W.E. DUELLMAN & A. MIRANDA-LEIVA. (2007): A taxonomic revision of *Atelopus pachydermus*, and description of two new (extinct?) species of *Atelopus* from Ecuador (Anura: Bufonidae). – *Zootaxa*, **1557**: 1-32.
- DRUNY, R.B. & E.A. WALLINGTON (1980): Carleton's histological technique. – Oxford, Oxford University Press.
- DUELLMAN, W.E. (2000): Leptodactylid frogs of the genus *Phrynopus* in northern Peru with de-

Two new harlequin frogs from Peru

- criptions of three new species. – *Herpetologica*, **56**: 273-285.
- FLANAGAN, J.N.M. & W.P. VELLINGA (2000): Tres bosques de neblina de Ayabaca: su avifauna y conservación. – Piura, ProAvesPerú.
- GRAY, P. (1983): Morphometrics of the *Atelopus ignescens* complex (Anura: Bufonidae). – UN-PUBL. M.S. Thesis, University of Kansas, Lawrence.
- GRAY, P. & D.C. CANNATELLA (1985): A new species of *Atelopus* (Anura, Bufonidae) from the Andes of northern Perú. – *Copeia*, **1985**: 910-917.
- LA MARCA, E., K.R. LIPS, S. LÖTTTERS, R. PUSCHENDORF, R. IBÁÑEZ, J.V. RUEDA-ALMONACID, R. SCHULTE, C. MARTY, F. CASTRO, J. MANZANILLA-PUPPO, J.E. GARCÍA-PÉREZ, F. BOLAÑOS, G. CHAVES, J.A. POUNDS, E. TORAL & B.E. YOUNG (2005): Catastrophic population declines and extinctions in Neotropical harlequin frogs (Bufonidae: *Atelopus*). – *Biotropica*, **37**: 190-201.
- LIPS, K. R., J. DIFFENDORFER, J. R. MENDELSON III, & M. W. SEARS (2008): Riding the wave: reconciling the roles of disease and climate change in amphibian declines. – *PLoS Biology* **6**(3): e72.
- LÖTTTERS, S. (1992): Ein neuer Harlekin-Frosch (Anura: Bufonidae: *Atelopus*) aus dem Chocó, West-Kolumbien. – *Sauria*, **14**: 27-30.
- LÖTTTERS, S. (1996): The Neotropical toad genus *Atelopus*. Checklist – Biology – Distribution. – Cologne, Vences & Glaw.
- LÖTTTERS, S. (2003): On the systematics of the harlequin frogs (Amphibia: Bufonidae: *Atelopus*) from Amazonia. III: A new, remarkably species from Cordillera Azul, Peru. – *Salamandra*, **39**: 169-180.
- LÖTTTERS, S. (2007): The fate of the harlequin toads – help through a synchronous multi-disciplinary approach and the IUCN 'Amphibian Conservation Action Plan'? – *Mitteilungen Museum für Naturkunde Berlin, Zoologische Reihe*, **83**: 69-73.
- LÖTTTERS, S. & I. DE LA RIVA (1998): Redescription of *Atelopus tricolor* Boulenger from southeastern Peru and adjacent Bolivia, with comments on related forms. – *Journal of Herpetology*, **32**: 481-488.
- LÖTTTERS, S. & M. HENZL (2000): A new species of *Atelopus* (Anura: Bufonidae) from the Serrania de Sira, Amazonian Peru. – *Journal of Herpetology*, **34**: 169-173.
- LÖTTTERS, S. & R. SCHULTE (2005): *Atelopus seminiferus*. – pp. 107 in RUEDA-ALMONACID, J.V., RODRÍGUEZ-MAHECHA, J.V., LÖTTTERS, S., LA MARCA, E., KAHN, T. & A. ANGULO (eds.): Ranas arlequines. – Bogotá, Conservación Internacional. Panamericana Formas e Impresos S. A.
- LÖTTTERS, S., W. HAAS, S. SCHICK & W. BÖHME (2002): On the systematics of the harlequin frogs (Amphibia: Bufonidae: *Atelopus*) from Amazonia. I: Description of a new species from Cordillera Azul, Peru. – *Salamandra*, **38**: 95-104.
- LÖTTTERS, S., E. LA MARCA, S. STUART, R. GAGLIARDO & M. VEITH (2004): A new dimension of global biodiversity loss? – *Herpetotropicos*, **1**: 29-31.
- LÖTTTERS, S., R. SCHULTE & W.E. DUELLMAN (2005a): A new and likely endangered species of *Atelopus* from the Andes of northern Peru (Anura: Bufonidae). – *Revista Española de Herpetología*, **18**: 101-109.
- LÖTTTERS, S., R. SCHULTE, J.H. CÓRDOVA & M. VEITH (2005b): Conservation priorities for harlequin frogs (*Atelopus*) of Peru. – *Oryx*, **39**: 343-346.
- LYNCH, J.D. (1993): A new harlequin frog from the Cordillera Oriental of Colombia (Anura, Bufonidae, *Atelopus*). – *Alytes*, **11**: 77-87.
- MYERS, C.W. & W.E. DUELLMAN (1982): A new species of *Hyla* from Cerro Colorado, and other tree frog records and geographical notes from western Panama. – *American Museum of Natural History Novitates*, **2752**: 1-32.
- PETERS, J.A. (1973): The frog genus *Atelopus* in Ecuador (Anura: Bufonidae). – *Smithsonian Contributions to Zoology*, **145**: 1-49.
- POUNDS, J.A., M.R. BUSTAMANTE, L.A. COLOMA, J.A. CONSUEGRA, M.P. FOGDEN, P.N. FOSTER, E. LA MARCA, K.L. MASTERS, A. MERINO-VITERI, R. PUSCHENDORF, S.R. RON, G.A. SANCHEZ-AZOFEIFA, C.J. STILL & B.E. YOUNG (2006): Widespread amphibian extinctions from epidemic disease driven by global warming. – *Nature*, **439**: 161-167.
- RIVERO, J.A. (1963): Five new species of *Atelopus* from Colombia, with notes on others forms from Colombia and Ecuador. – *Caribbean Journal of Science*, **3**: 103-124.

- RIVERO, J.A. & M.A. SERNA (1991): A new species of *Atelopus* (Amphibia, Bufonidae) from Antioquia, Colombia. – *Brenesia*, **36**: 15-20.
- SAVAGE, J.M. & W.R. HEYER (1967): Variation and distribution of the tree frog genus *Phyllomedusa* in Costa Rica, Central America. – *Beiträge zur Neotropischen Fauna*, **5**: 111-131.
- SAVAGE, J.M. & W.R. HEYER (1997): Digital webbing formulae for anurans: a refinement. – *Herpetological Review*, **28**: 131.
- VENEGAS, P.J. & J. BARRIO (2005): A new species of harlequin frog (Anura: Bufonidae: *Atelopus*) from the northern Cordillera Central, Peru. – *Revista Española de Herpetología*, **29**: 103-112.
- VENEGAS, P. & D. CISNEROS (2005): *Atelopus* sp. 18. – pp. 154 in RUEDA-ALMONACID, J.V., J.V. RODRÍGUEZ-MAHECHA, S. LÖTTERS, E. LA MARCA, T. KAHN & A. ANGULO (eds.): *Ranas arlequines*. – Bogotá, Conservación Internacional. Panamericana Formas e Impresos S. A.

Appendix

Material examined in addition to the new species *Atelopus pachydermus* sensu stricto: PERU: Cajamarca: Grutas Cutervo, MUSM 17027-17031; Departamento Amazonas: Campredondo, MUSM 6524. *Atelopus peruensis*: PERU: Cajamarca: Cajamarca Hacienda Taulis MUSM 13602-13603, Yanac, MUSM 13604-13606, Cumbe, MUSM 13813-13816, Cordillera de Kunulka, MUSM 1904-1912; Ancash: Yurayacu, MUSM 1920-1929, Charco, MUSM 6596-6610, 7128-7131.

Manuscript received: 18 January 2008

Authors' addresses: PABLO J. VENEGAS, Investigador Asociado-Centro de Ornitología y Biodiversidad (CORBIDI), Santa Rita 117, Huertos de San Antonio, Surco, Lima, Peru, E-Mail: sancarranca@yahoo.es; ALESSANDRO CATENAZZI, Department of Biological Sciences, Florida International University, Miami FL 33199, USA; KAREN SIU-TING, Departamento de Herpetología, Museo de Historia Natural, Universidad Nacional Mayor de San Marcos, Av. Arenales 1256, Lima, Peru; JORGE CARRILLO, Departamento de Ciencias Biológicas y Fisiológicas, Universidad Peruana Cayetano Heredia, Lima, Peru.