

A NEW SPECIES OF FROG OF THE *ELEUTHERODACTYLUS*  
*LACRIMOSUS* ASSEMBLAGE (LEPTODACTYLIDAE) FROM THE  
WESTERN AMAZON BASIN, WITH COMMENTS ON THE UTILITY  
OF CANOPY SURVEYS IN LOWLAND RAINFOREST

JUAN M. GUAYASAMIN<sup>1,6,8</sup>, SANTIAGO R. RON<sup>2,6</sup>, DIEGO F. CISNEROS-HEREDIA<sup>3</sup>,  
WILLIAM LAMAR<sup>4</sup>, AND SHAWN F. MCCRACKEN<sup>5,7</sup>

<sup>1</sup>Natural History Museum & Biodiversity Research Center, Department of Ecology and Evolutionary Biology,  
The University of Kansas, Lawrence, KS 66045-7561, USA

<sup>2</sup>Section of Integrative Biology and Texas Memorial Museum, The University of Texas, Austin, TX 78712, USA

<sup>3</sup>Colegio de Ciencias Biológicas & Ambientales, Universidad San Francisco de Quito, Ave. Interoceánica,  
Campus Cumbayá, Edif. Maxwell, Decanato. Casilla Postal 17-12-841, Quito, Ecuador

<sup>4</sup>University of Texas at Tyler, Department of Biology, 3900 University Blvd., Tyler, TX 75799, USA

<sup>5</sup>Texas State University, Department of Biology, 601 University Drive, San Marcos, TX 78666, USA

<sup>6</sup>Museo de Zoología, Centro de Biodiversidad y Ambiente, Escuela de Biología, Pontificia Universidad Católica  
del Ecuador, Av. 12 de Octubre y Roca, Aptdo. 17-01-2184, Quito, Ecuador

<sup>7</sup>Tadpole Organization, 2214 South First Street, Austin, TX 78704, USA

**ABSTRACT:** We describe a new species of *Eleutherodactylus* from the lowlands of the western Amazon Basin. The new species is referred to the *Eleutherodactylus unistrigatus* group, *lacrimosus* assemblage. It differs from other members of the group by having a dorsal olive-green coloration with an interorbital creamy yellow stripe that extends posterolaterally and reaches the level of the sacrum, and low ulnar and tarsal tubercles. The new species inhabits western Amazon tropical rainforests and has been found in arboreal bromeliads by day and on vegetation by night. We discuss the effect of lack of sampling in the forest canopy in our understanding of tropical amphibian communities. Based on work conducted at two localities in Ecuadorian Amazonia, we find that even limited sampling effort in the canopy can greatly improve efficiency of biological inventories.

**Key words:** Anura; Canopy sampling; Ecuador; *Eleutherodactylus aureolineatus*; *E. lacrimosus*; *E. unistrigatus*; Leptodactylidae; New species; Peru

THE GENUS *Eleutherodactylus* comprises 621 recognized species (Amphibiaweb, 2005) distributed in Central and South America, as well as the West Indies. The *Eleutherodactylus lacrimosus* assemblage is a phenetic subgroup of the larger *E. unistrigatus* group (sensu Lynch and Duellman, 1997) and currently contains 14 species: *Eleutherodactylus apiculatus* Lynch and Burrowes 1990 (but see Heyer and Hardy, 1991:444); *E. boulengeri* Lynch 1981; *E. brevifrons* Lynch 1981; *E. bromeliaceus* Lynch 1979; *E. dorsopictus* Rivero and Serna 1988 "1987"; *E. eremitus* Lynch 1980; *E. lacrimosus* (Jiménez de la Espada 1875); *E. mendax* Duellman 1978a; *E. olivaceus* Köhler, Morales, Lötters, Reichle, and Aparicio 1998; *E. petersorum* Lynch 1991; *E. prolixodiscus* Lynch 1978; *E. schultzei* Duellman 1990; *E. tayrona* Lynch and Ruíz-

Carranza 1985; and *E. zimmermanae* Heyer and Hardy 1991. Most members of this assemblage likely are bromeliad-dwelling and have a small body size (SVL in males, 14.5–26.6 mm; in females, 20.3–33.8 mm) and broad, flat, pointy heads.

The morphological resemblance among the species in the *Eleutherodactylus lacrimosus* assemblage has been explained as the result of convergent evolution in response to their microhabitat use (bromeliads; Lynch and Ruíz-Carranza, 1985), rather than as a result of common ancestry, although no formal test has been performed to distinguish between these two hypotheses. Until robust phylogenetic hypotheses are available, the *E. lacrimosus* assemblage is recognized only as a matter of convenience (Lynch and Ruíz-Carranza, 1985).

Recent collection efforts in the canopy of Amazon rainforest and examination of specimens previously identified as *Eleutherodactylus lacrimosus* revealed the presence of an

<sup>8</sup> CORRESPONDENCE: e-mail, juanm@ku.edu

undescribed species. Herein, we describe this new species and discuss the effect of sampling the forest canopy in our understanding of tropical amphibian communities.

#### MATERIALS AND METHODS

The diagnosis and description of the new species follow those of Lynch and Duellman (1997). We examined alcohol-preserved specimens from the herpetological collections at Museo de Zoología of the Universidad Católica del Ecuador, Quito (QCAZ); Universidad San Francisco de Quito, Quito (DFCH-USFQ); Natural History Museum of The University of Kansas, Lawrence (KU); and The Natural History Collection at Texas A&M University – Texas Cooperative Wildlife Collection, College Station (TCWC). In addition to the type series of the new species, specimens examined are listed in Appendix I; one of us (WL) examined an additional specimen (CRG 931; adult female from Reserva Allpahuayo, 25 km S Iquitos) of the new species that currently forms part of a collection by Carlos Rivera G.

Morphological measurements were taken as described in Guayasamin (2004) and are: (1) snout–vent length (SVL); (2) tibia length; (3) foot length; (4) head length; (5) head width; (6) interorbital distance; (7) upper eyelid width; (8) internarial distance; (9) eye-to-nostril distance; (10) snout–eye distance; (11) eye diameter; (12) tympanum diameter; (13) eye-to-tympanum distance; (14) radioulna length; (15) hand length; (16) Finger-I length. Sexual maturity was determined by the presence of eggs or convoluted oviducts in females or by the presence of vocal slits in males. Color patterns in life were taken from field notes and color photographs.

At Yasuní Scientific Research Station of the Universidad Católica del Ecuador (YSRS), visual encounter surveys (mainly ground-level VES) have been carried out regularly since 1995, and sporadic canopy searches (especially in tank bromeliads) were carried out during one week in May 2002.

At Tiputini Biodiversity Station of the Universidad San Francisco de Quito (TBS), surveys (ground-level transect VES and quadrats) have been carried out since 1998; at this locality, canopy surveys were conducted within

a 100 m-long system of canopy bridges, and annual bromeliad inspections were performed (surveys of all bromeliads on three trees once per year). During the VES, most of the amphibians found were collected; thus, the number of specimens recorded was used as a proxy for inventory sampling effort.

SFM conducted bromeliad patch sampling using single-rope climbing technique to access canopy bromeliads in July and August of 2004. Two trees in each of four quadrat plots were surveyed; five bromeliads were removed from each tree at varying vertical heights and placed in large plastic bags to be lowered to the forest floor. Then, the obtained bromeliads ( $n = 40$ ) were searched by removal of individual leaves to facilitate collection of all anurans.

#### *Eleutherodactylus aureolineatus* sp. nov.

Fig. 1A

*Eleutherodactylus lacrimosus* — Duellman, 1978.

*Eleutherodactylus* sp. nov.—Ron, 2001; Read, 2000; Cisneros-Heredia, 2003.

*Holotype*.—QCAZ 20712 (field no. SC 10141), an adult male collected by Italo Tapia and SRR at the Yasuní Scientific Research Station, Universidad Católica del Ecuador (76° 24' 19" W, 00° 40' 32" S; altitude 230 m), Provincia de Orellana, Ecuador, on 7 May 2002.

*Paratopotypes*.—QCAZ 19534, adult female collected by Samael Padilla on December 3, 2001; QCAZ 20713 (field no. 10142), subadult male collected by Italo Tapia and SSR on 7 May 2002.

*Paratypes*.—Ecuador: Provincia de Orellana: Tiputini Biodiversity Station, Universidad San Francisco de Quito (76° 10' 19" W, 00° 37' 05" S, 190–250 m): DFCH-USFQ 0443, adult male collected by DFCH and Andrés León on 15 February 2001; DFCH-USFQ 0559, juvenile collected by DFCH on 31 July 2001; DFCH-USFQ 0734, subadult male, and DFCH-USFQ 0736, adult female collected by DFCH and Andrés León on 15 August 2002; TCWC 90334, juvenile collected by SFM on 18 May 2004; TCWC 90335, 90338, 90339, adult males, TCWC 90336), subadult female, TCWC 90337, 90340, adult females, and TCWC 90341, juvenile male collected by

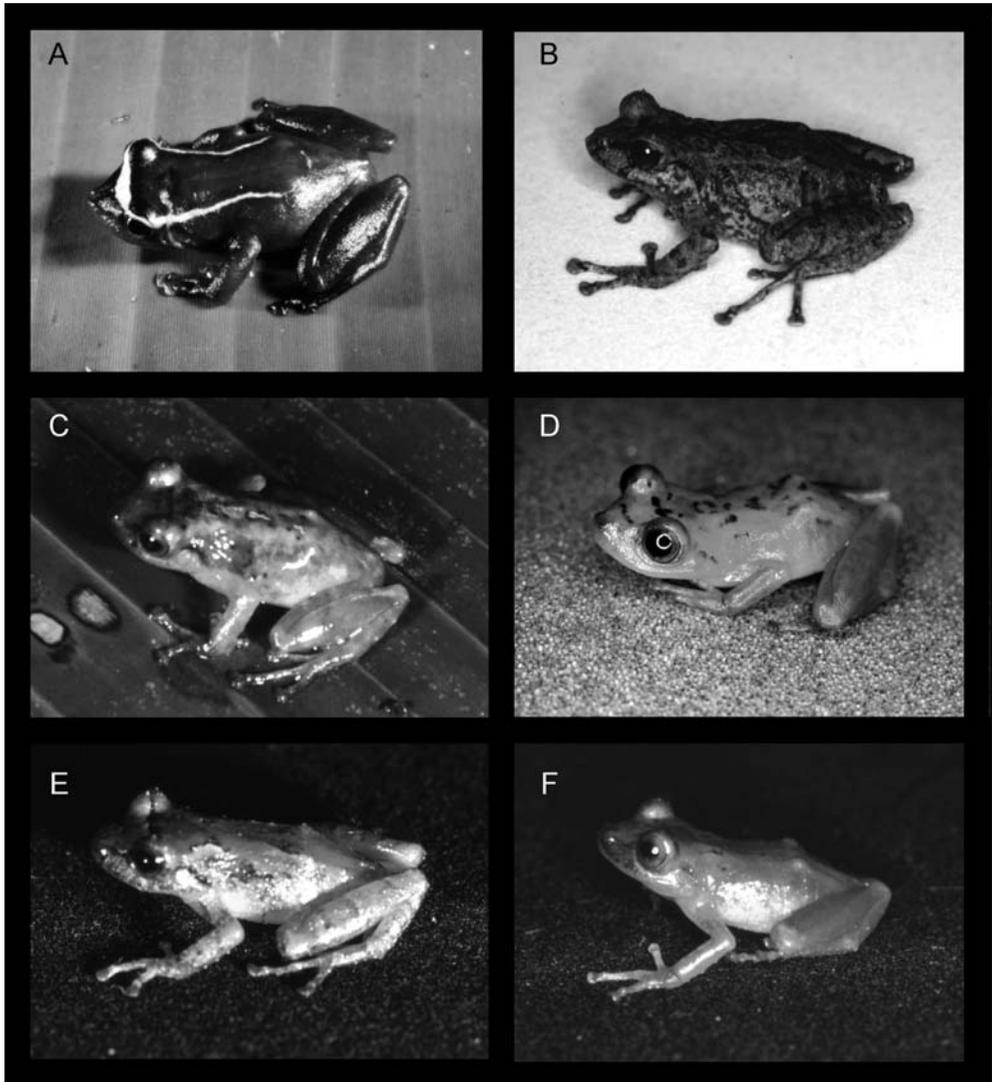


FIG. 1.—Species in the *Eleutherodactylus lacrimosus* assemblage. (A) *Eleutherodactylus aureolineatus*, QCAZ 19534, female, SVL 27.8 mm (photo by SRR); (B) *E. boulengeri* KU 169055, female, SVL 30.6 mm (William E. Duellman); (C) *E. eremitus*, KU 165884, male, SVL 19.7 mm (WED); (D) *E. lacrimosus*, KU 119513, female, SVL 24.5 mm (John D. Lynch); (E) *E. mendax*, KU 162290, SVL 19.6 mm (WED); (F) *Eleutherodactylus petersorum*, KU 165993, juvenile female, SVL 20.7 mm (WED). Color photographs are available at AmphibiaWeb (<http://elib.cs.berkeley.edu/aw/>).

SFM on 31 July 2004; and TCWC 90342, adult female collected by SFM on 08 Aug 2004; *Provincia de Sucumbíos*: Limoncocha (00° 24' S, 76° 37' W; altitude 220 m): KU 106967 (adult male) and 104623 (juvenile) collected by W. E. Duellman on 22 November 1966 and 16 August 1966, respectively; KU 123402, juvenile collected by M. L. Crump on 14 July 1968; Santa Cecilia (00° 03' N, 76° 58' W; altitude

340 m): KU 148902, 148906, adult males collected by M. L. Crump on 05 October 1971 and 25 February 1972, respectively. *Peru: Departamento de Loreto*: Explornapo Lodge, junction between Río Sucusari and Río Napo (03° 16' S, 72° 54' W): KU 220426, adult female collected by WL on 17 June 1992.

*Diagnosis*.—A member of the *Eleutherodactylus unistrigatus* group, *lacrimosus* assemblage

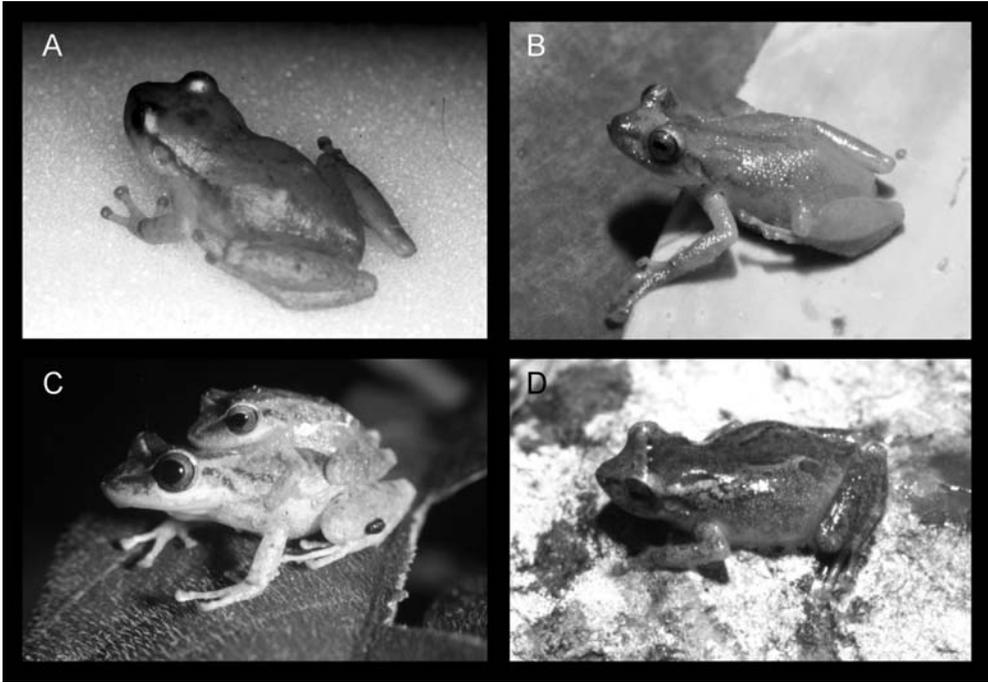


FIG. 2.—Species in the *Eleutherodactylus lacrimosus* assemblage. (A) *Eleutherodactylus prolixodiscus*, KU 132733, male, SVL 25.1 mm (photo by Stephan R. Edwards); (B) *E. schultei*, KU 212222, male, SVL 27.4 mm (William E. Duellman); (C) *E. zimmermanae*, amplexant pair, NMW 32112:2–3 (Walter Hödl); (D) *E. bromeliaceus*, KU 212214, male, SVL 22.5 mm (WED). Color photographs are available at AmphibiaWeb (<http://elib.cs.berkeley.edu/aw/>).

(as defined by Lynch and Duellman, 1980, 1997; Lynch and Ruiz-Carranza, 1985) having (1) skin texture of dorsum finely shagreen, that on the venter areolate (sensu Lynch and Duellman, 1997); discoidal fold low; dorsolateral folds absent; (2) tympanic membrane not differentiated in males and slightly evident in females; tympanic annulus evident, with supratympanic fold obscuring upper and posterodorsal edges, horizontal diameter of tympanum 31–39% of eye diameter; (3) snout subacuminate in dorsal view, protruding in profile; (4) upper eyelid lacking tubercles or with one small tubercle; cranial crests absent; (5) dentigerous process of the vomer triangular, each bearing 0–6 teeth; (6) males with vocal slits and median subgular vocal sac; white nuptial pads present; (7) first finger shorter than the second; Fingers III–IV bearing rounded discs about twice as wide as digits; (8) fingers with narrow lateral fringes; (9) antibrachial tubercle evident, ulnar tubercles low or absent; (10) tarsal tubercles low or absent; (11) inner metatarsal tubercle

oval, two-to-three times as long as round outer metatarsal tubercle; supernumerary plantar tubercles low, at the base of Toes III and IV; (12) toes with narrow lateral fringes; webbing absent; fifth toe much longer than third; (13) in life, males with dorsum olive green with an interorbital golden yellow stripe that extends above the eyes and dorsolaterally to the sacrum, and females with dorsum olive brown to dark brown with an interorbital creamy yellow stripe that extends above the eyes and dorsolaterally to the sacrum; venter bright yellow to greenish cream; posterior surfaces of thighs olive green; (14) adults small, SVL in males 19.7–28.8 mm ( $\bar{x} = 23.6 \pm 2.77$ ,  $n = 9$ ), in females 26.3–30.5 mm ( $\bar{x} = 27.8 \pm 1.86$ ,  $n = 7$ ); males with white testes (mesorchium).

*Comparison with similar species.*—*Eleutherodactylus aureolineatus* differs from all other species of the *E. lacrimosus* assemblage (i.e., *E. apiculatus*, *E. boulengeri*, *E. brevifrons*, *E. bromeliaceus*, *E. dorsopictus*, *E. eremitus*, *E. lacrimosus*, *E. mendax*, *E. petersorum*, *E. prolixodiscus*, *E. schultei*, *E. tayr-*

*ona*, *E. zimmermanae*) by its olive-green dorsal coloration with a creamy-yellow interorbital stripe that extends above the eyes and dorsolaterally to the sacrum (Figs. 1, 2). Additionally, *Eleutherodactylus aureolineatus* differs from the sympatric *E. lacrimosus* by lacking tubercles on dorsum (few tubercles present in *E. lacrimosus*) and by being larger (see Table 1). Differences among species in the *E. lacrimosus* assemblage are summarized in Table 1.

*Description of holotype*.—Adult male (QCAZ 20712) with head as wide as long; snout subacuminate in dorsal view and protruding in lateral view, relatively short (snout–eye distance 16.9% SVL), with small papilla at tip (Fig. 3); in lateral view, canthus rostralis distinct; loreal region slightly concave; nostrils protuberant, directed dorsolaterally; interorbital area flat, broader than upper eyelid (upper eyelid width 61.8% interorbital distance); cranial crests absent; upper eyelid lacking tubercles; tympanic membrane not differentiated from surrounding skin; tympanic annulus distinct, round, with supratympanic fold obscuring upper and posterodorsal edges of annulus (Fig. 3); tympanum diameter 34.4% of eye diameter; postrictal tubercles absent. Choanae small, nearly elliptical, not concealed by palatal shelf of maxillary; dentigerous process of the vomer triangular, widely separated, posteromedial to choanae, each bearing two or five small teeth (bilateral variation within individual); shortest distance between dentigerous processes about 36% distance between choanae; tongue longer than wide, granular, with small notch in posterior border.

Texture of skin of dorsum and flanks shagreen, dorsolateral folds absent; venter areolate; discoidal fold low; cloacal sheath absent. Forearm slender; radio–ulna length 20.6% SVL; ulnar tubercles and ulnar fold absent; hand length longer than radio–ulna length (hand length 26.7% SVL); fingers with narrow lateral fringes; relative lengths of fingers I < II < IV < III; palmar tubercle incompletely bifid, thenar tubercle oval (Fig. 4); subarticular tubercles round, prominent; supernumerary palmar tubercles present at the base of all fingers (Fig. 4); disc cover of Finger I slightly expanded, those of Fingers II–IV extensively expanded (Fig. 4); outer discs of fingers as wide as those of toes; all disc

covers with elliptical ventral pads defined by circummarginal grooves.

Hind limbs relatively slender; tibia length 53.1% SVL; foot length 82.9% of tibia length; tarsal fold and tarsal tubercles absent; heel (tibiotarsal articulation) lacking tubercles; toes with narrow lateral fringes (Fig. 4); subarticular tubercles round, prominent; inner metatarsal tubercle oval, about  $2.4 \times$  the size of subconical outer tubercle; supernumerary plantar tubercles low, at the base of toes (Fig. 4); disc covers slightly expanded; toes with defined pads; disc pads nearly elliptical; relative lengths of toes I < II < III < V < IV (Fig. 4); tip of Toe V reaching proximal border of distal subarticular tubercle of Toe IV; tip of Toe III reaching distal border of medial subarticular tubercle of Toe IV.

*Coloration of holotype in life*.—Dorsum light olive green with an interorbital creamy yellow stripe that extends above the eyes and dorsolaterally to the sacrum, dorso-lateral portion of stripe faint; surfaces of hind limbs and forearm olive green; dorsal surface of arm greenish yellow; flanks olive green with lighter flecks. Venter bright yellow; throat greenish cream, becoming pale gray towards the jaw; ventral surfaces of hind limbs greenish salmon; tibiofibula externally visible, white; sides of head olive green, becoming greenish cream towards the lips. Iris reddish bronze with reddish brown median horizontal streak (S. R. Ron, field notes, 8 May 2002).

*Coloration of holotype in ethanol*.—Dorsum brown with an interorbital whitish stripe that extends above the eyes and dorsolaterally to the sacrum, posterior portion of stripe faint; surfaces of limbs brown; flanks light brown; groin cream. Throat, venter, and underside of limbs cream; palms and soles cream with some brown pigmentation on external fingers and toes.

*Measurements of holotype (mm)*.—SVL = 24.3; tibia length = 12.9; foot length = 10.7; head length = 9.4; head width = 9.3; upper eyelid width = 2.1; interorbital distance = 3.4; eye diameter = 3.2; eye-to-nostril distance = 2.9; snout-to-eye distance = 4.1; tympanum diameter = 1.1; eye-to-tympanum distance = 1.1; internarial distance = 1.8; radioulna length = 5.0; hand length = 6.5; finger I length = 4.3; finger II length = 4.4. For morphometric variation, see Table 2.

TABLE 1.—Diagnostic morphological characters in species of the *Eleutherodactylus lacrimosus* assemblage. For *E. lacrimosus*, SVL is given for lowland (<800 m) and highland (900–1100 m) populations (adults only).

	SVL males	SVL females	Tubercles on upper eyelid	Uhar tubercles	Tarsal tubercles	Dorsal coloration in life	Source
<i>E. apiculatus</i>	17.8–21.8	21.6–26.3	One small nonconical tubercle	Absent	Present, but indistinct	Tan or yellowish tan with or without irregular shaped blotches; some with middorsal yellow stripe or fine yellow stripes	Lynch and Duellman, 1997; this work
<i>E. aureolineatus</i>	19.7–28.8	26.3–30.5	Absent or one low tubercle present	Low or absent	Low or absent	Olive green with creamy yellow interorbital bar and dorsolateral stripes that extend posterolaterally to the level of sacrum	This work
<i>E. boutengeri</i>	18.6–25.6	27.3–33.8	Present, numerous and nonconical	Present	Low or absent	Orange-tan to brown with darker spots or marks; some with dark dorsolateral stripes; interorbital bar usually present	Lynch, 1981; this work
<i>E. brevifrons</i>	15.1–19.7	21.2–25.0	Low or absent	Absent or present, but indistinct	Low or absent	Pale yellow to brown with indistinct to bold brown markings washed with green; some with dorsolateral stripes	Lynch, 1981; this work
<i>E. bromeliaceus</i>	16.7–23.2	22.9–28.1	Two or three small tubercles	Absent	Present, low	White with or without spots and/or reticulation	Lynch, 1979
<i>E. dorsopictus</i>	19.0–22.0	21.6–31.6	?	Present, small	Low or absent	?	Rivero and Serna, 1988 “1987”
<i>E. eremitus</i>	17.2–21.8	27.1–27.6	One conical tubercle or several small tubercles	Absent or present, but indistinct	Present, small	Green, usually with darker markings; some with black spots or redish brown dorsolateral stripes	Lynch and Duellman, 1997; this work
<i>E. lacrimosus</i>	Low: 16.1–20.0 High: 19.6–23.7	Low: 20.6–24.4 High: 24.4–32.5	Absent	Absent	Absent	Pale golden brown with or without brown spotting	Lynch and Duellman, 1980
<i>E. mendax</i>	19.4–21.7	22.6–28.0	Low or absent	Present	Present	Green with various markings; some with orange-tan or yellow-tan dorsolateral stripes	Duellman, 1978a; this work
<i>E. olivaceus</i>	17.8–20.7	—	Two or three small tubercles	Present, small	Present, small	Olive green with black spots and markings; cream interorbital bar present	Köhler et al., 1998

TABLE 1.—Continued

	SVL males	SVL females	Tubercles on upper eyelid	Ulnar tubercles	Tarsal tubercles	Dorsal coloration in life	Source
<i>E. petersorum</i>	14.5–19.9	20.3–23.1	One conical tubercle	Absent	Absent	Usually uniform pale green to dull green; some tan or brown with or without brown markings	Lynch and Duellman, 1980
<i>E. prolixodiscus</i>	19.3–25.4	23.0–26.7	Low or absent	Present, low	Absent	Dorsum with distinct green patch; canthal and postocular stripe (ending about sacrum) present	Lynch, 1978; this work
<i>E. schultzei</i>	23.5–26.6	28.4–34.0	Numerous, low	Present, low	Numerous, low	Tan, reddish brown, or green, bordered or not by narrow dark brown line from snout to point above vent	Duellman, 1990
<i>E. tayrona</i>	15.3–25.1	22.6–30.2	Low or absent	Low or absent	Absent	Reddish-brown; some with cream to dull orange vertebral stripe	Lynch and Ruiz-Carranza, 1985; this work
<i>E. zimmermanae</i>	19.1–21.2	22.4–25.8	Several tubercles	Present	Present	Light to medium brown with darker markings; yellow interorbital bar present or absent	Heyer and Hardy, 1991

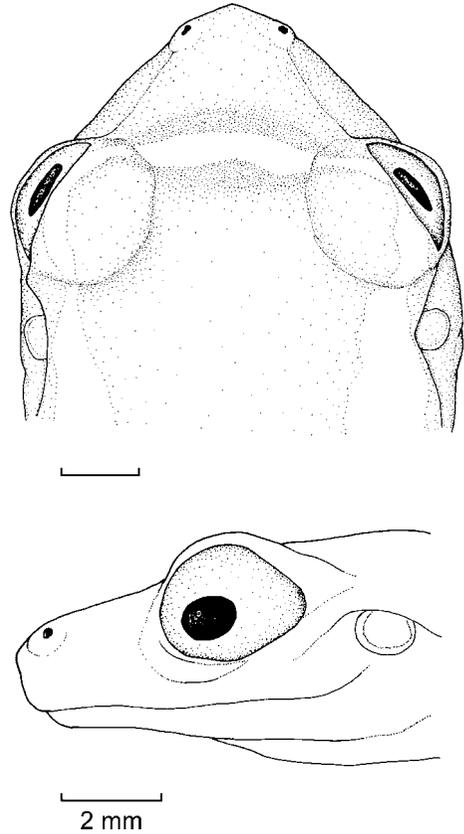


FIG. 3.—Dorsal (A) and lateral (B) views of head of holotype of *Eleutherodactylus aureolineatus*, QCAZ 20712, SVL = 24.3 mm.

*Variation*.—In some specimens, the snout is round in dorsal view and lacks the papilla at tip (QCAZ 20713, KU 123402, DFCH-USFQ 0559). In one female (DFCH-USFQ 0736), the papilla is poorly defined. On the inner margin of the tarsus of most individuals (KU 104623, 106967, 123402, 148902, 148906, DFCH-USFQ 0734, 0443, TCWC 90335–42), three low tubercles are evident under magnification. The absence of tarsal and ulnar tubercles in some of the specimens of *Eleutherodactylus aureolineatus*, including the holotype, may be a preservation artifact. We have observed that low tubercles are distinguishable in living individuals, but seem to be absent when examining preserved material.

The number of teeth on the dentigerous processes of the vomers is variable; some specimens (KU 148906, QCAZ 19534, 20713,

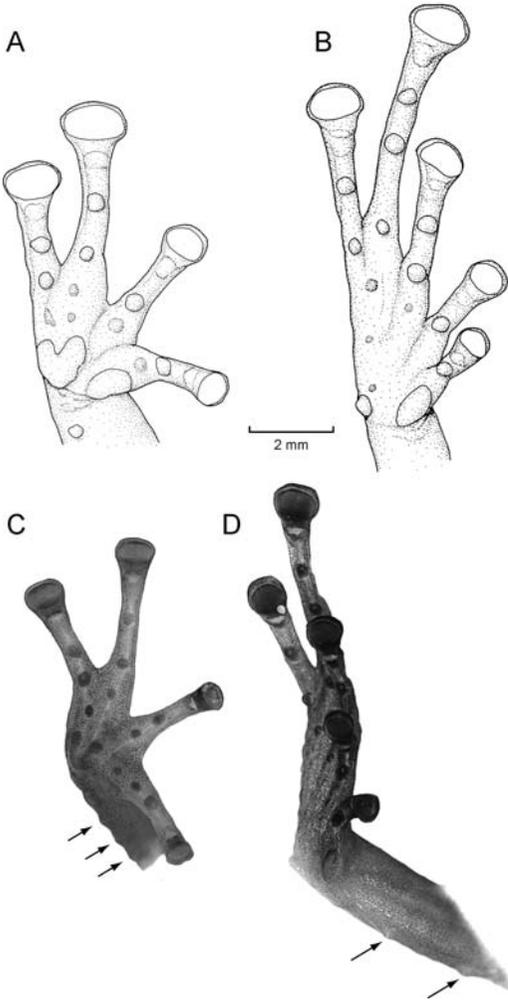


FIG. 4.—Ventral view of hand and foot of *Eleutherodactylus aureolineatus*. (A) Hand, QCAZ 19534, female; (B) foot, QCAZ 19534, female; (C) hand and forearm, arrows indicate low ulnar tubercles, TCWC 90338, male; (D) foot and tarsus, arrows indicate low tarsal tubercles, TCWC 90338, male.

TABLE 2.—Measurements (in mm) and morphological proportions (in percentages) of adult males and females of *Eleutherodactylus aureolineatus* (range over mean  $\pm$  standard deviation).

	Males n = 9	Females n = 7
SVL	19.7–28.8	26.3–30.5
	23.6 $\pm$ 2.77	27.5 $\pm$ 1.58
Tibia length	11.5–15.3	13.5–15.4
	12.8 $\pm$ 1.33	14.5 $\pm$ 0.68
Foot length	9.2–12.6	11.3–12.5
	10.4 $\pm$ 1.24	11.9 $\pm$ 0.40
Head length	8.6–11.1	10.1–10.8
	9.1 $\pm$ 0.87	10.4 $\pm$ 0.22
Head width	8.7–12.0	10.2–12.2
	9.5 $\pm$ 1.19	11.1 $\pm$ 0.70
Upper-eyelid width	2.1–2.9	2.3–2.9
	2.3 $\pm$ 0.29	2.5 $\pm$ 0.21
Interorbital distance	2.7–4.3	3.3–4.3
	3.2 $\pm$ 0.56	3.7 $\pm$ 0.33
Eye diameter	2.7–4.1	3.3–4.0
	3.25 $\pm$ 0.42	3.6 $\pm$ 0.27
Eye-to-nostril distance	2.6–3.6	3.0–3.4
	2.9 $\pm$ 0.34	3.3 $\pm$ 0.15
Snout-to-eye distance	3.9–5.2	4.2–5.0
	4.2 $\pm$ 0.45	4.7 $\pm$ 0.29
Tympanum diameter	1.0–1.5	1.2–1.5
	1.2 $\pm$ 0.18	1.3 $\pm$ 0.15
Eye-to-tympanum distance	0.7–1.6	0.9–1.6
	1.1 $\pm$ 0.34	1.2 $\pm$ 0.27
Internarial distance	1.7–2.5	2.0–2.7
	1.9 $\pm$ 0.29	2.2 $\pm$ 0.25
Radioulna length	4.9–6.7	5.7–6.4
	5.35 $\pm$ 0.62	6.0 $\pm$ 0.27
Hand length	5.8–7.9	7.4–8.0
	6.5 $\pm$ 0.74	7.6 $\pm$ 0.25
Finger I length	2.8–4.85	3.9–5.3
	4.0 $\pm$ 0.66	4.9 $\pm$ 0.46
Finger II length	4.0–5.5	5.1–5.7
	4.8 $\pm$ 0.76	5.3 $\pm$ 0.30
Tibia length/SVL	50.4–58.4	48.8–58.2
Foot length/SVL	40.9–46.7	41.0–46.2
Head width/SVL	38.3–44.2	38.6–42.5
Head length/SVL	36.8–44.7	33.8–39.5
Radioulna length/SVL	20.6–25.9	18.7–24.2
Upper eyelid width/		
Interorbital distance	60.0–86.2	60.5–81.8
Tympanum diameter/		
Eye diameter	34.4–43.3	34.3–42.1
Finger I length/Finger		
II length	88.7–97.7	90.1–96.6

DFCH-USFQ 0734, TCWC 90335, 90337, 90338, 90340, 90342) have 5 or 6 teeth, one specimen (TCWC 90339) has 4 teeth, whereas others (KU 104623, 106967, 123402, DFCH-USFQ 0443, 0736, TCWC 90336, 90341) have only 1 to 3 or lack them altogether (KU 148902, TCWC 90334). Two to three small ulnar tubercles are present in CRG 931, TCWC 90335, 90337–40, 90342. In life, males have a pale (DFCH-USFQ 0443, TCWC 90339) or dark (QCAZ 20713, DFCH-USFQ

0734, TCWC 90335, 90338, 90341) olive-green dorsum; the interorbital stripe is bright golden to yellow during night and pale golden during day, and it extends above the eyes and dorsolaterally down to the sacrum or to mid-flanks; coloration of ventral surfaces of arms and legs is similar to that on venter. Females have a darker coloration, with olive brown to dark brown dorsal coloration and the

interorbital stripe is creamy yellow (DFCH-USFQ 0736, TCWC 90337, 90340, 90342), coloration of ventral surfaces of arms and legs are dark brown, unlike venter coloration. Venter coloration varies from bright yellow (QCAZ 20712, DFCH-USFQ 0736, 443, TCWC 90335) and pale cream (DFCH-USFQ 0734, TCWC 90336, 90339, 90341), to greenish creamy (QCAZ 20713, TCWC 90337, 90338, 90340, 90342). Posterior surfaces of thighs vary from olive green to dark brown. Juvenile (DFCH-USFQ 0559) with dark brown dorsum, ventral surfaces white bluish, posterior surfaces brown with indistinct darker transversal bands and flecks, cream interorbital stripe, iris dark brown. In preservative, the soles and palms have a pale brown coloration (CRG 931; DFCH-USFQ 0736); the dorsum is creamish brown (KU 148906), reddish brown (DFCH-USFQ 0443) or dark brown (DFCH-USFQ 0736) with cream dorsolateral stripes.

*Distribution and natural history.*—*Eleutherodactylus aureolineatus* has been found at localities below 350 m in elevation, in the upper Amazon Basin of eastern Ecuador and Peru (Fig. 5). The vegetation type at the Ecuadorian localities is Amazonian Evergreen Lowland Forest (Palacios et al., 1999). The YSRS and the TBS are located on the bank of the Río Tiputini at elevations between 190–250 m. Limoncocha is a oxbow lake on the north bank of the Río Napo at an elevation of 220 m. At these localities, the vegetation is composed of terra firme forest (nonflooded forest), varzea (flooded forest), and seasonally flooded forest. The vegetation type and climate at Santa Cecilia (Provincia de Sucumbíos, 340 m) have been described in detail by Duellman (1978b). On 7 May 2002, the holotype and one subadult male (QCAZ 20713) were collected by day in a tank bromeliad, at a height of 25 m, on a tree in terra firme forest. In the same bromeliad, an adult male and at least 10 tadpoles of *Osteocephalus planiceps* (e.g., QCAZ 20873) were found. On 7 May 2002, in a tree hole 7 m below the same bromeliad, an adult male and female and several tadpoles (QCAZ 20875) of *Phrynohyas resinifictrix* were found; the next day, an additional adult female of *P. resinifictrix* was collected in the same hole (S. R. Ron, fieldnotes). An adult female *E. aureolineatus* (QCAZ 19534) was

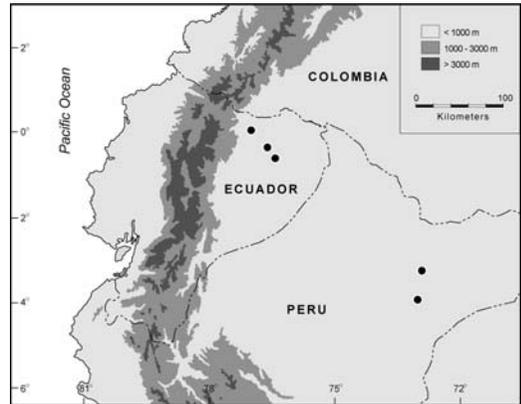


FIG. 5.—Distribution of *Eleutherodactylus aureolineatus* (circles). Map modified from Torres-Carvajal (2005).

collected by night over a window on a building of the YSRS on 3 December 2001. An adult male *E. aureolineatus* (DFCH-USFQ 0443) was collected while calling by night over a leaf ca. 45 m height on a Ceiba tree in terra firme forest. A subadult male (DFCH-USFQ 0734) and an adult female (DFCH-USFQ 0736) were collected by day inside a bromeliad ca. 40 m height on a tree in terra firme forest (D. F. Cisneros-Heredia, fieldnotes). A female *E. aureolineatus* (not collected) was observed during day inside a bromeliad ca. 40 m height, together with an adult *Dendrobates ventrimaculatus* (D. F. Cisneros-Heredia, fieldnotes). A juvenile *E. aureolineatus* (TCWC 90334) was collected by night ca. 30 m height on a handrail of a wooden canopy tower surrounding a Ceiba tree in terra firme forest at TBS on 18 May 04; two adult males (TCWC 90335, 90338), one adult female (TCWC 90337) and one juvenile female (TCWC 90336) were collected by day inside a bromeliad ca. 38 m height on a tree in terra firme forest during bromeliad patch sampling on 31 July 2004; on the same tree, an adult male (TCWC 90339), an adult female (TCWC 90340) and a juvenile male (TCWC 90341) were collected by day inside a bromeliad ca. 35.5 m height on 31 July 2004 (S. F. McCracken, fieldnotes). An adult female (TCWC 90342) was collected by day inside a bromeliad ca. 23.5 m height on a tree in terra firme forest during bromeliad patch sampling on 8 Aug. 2004; on the same tree, an *E. aureolineatus* (not collected) was observed by day inside a bromeliad ca. 23.5 m height on

8 Aug. 2004 (S. F. McCracken fieldnotes). Two males *E. aureolineatus* (KU 148902, 148906) were found at night on low vegetation (W. E. Duellman, fieldnotes); one juvenile (KU 123402) was found on forest floor by day (M. L. Crump, fieldnotes), while another juvenile (DFCH-USFQ 0559) was found in low vegetation (50 cm) by night (D. F. Cisneros-Heredia, fieldnotes). Twelve out of fifteen adults with ecological data have been found at heights >20 m suggesting that *E. aureolineatus* is predominantly a canopy dweller.

*Etymology.*—The specific name *aureolineatus* comes from the Latin words *aureus* meaning golden, and *linea* meaning line. The name is used in reference to the dorso-lateral golden stripe characteristic of the new species.

*Remarks.*—Most of the diversity of the *Eleutherodactylus lacrimosus* assemblage is found in the cloud forest of the Andes. Only five species (*E. aureolineatus*, *E. bromeliaceus*, *E. lacrimosus*, *E. mendax*, and *E. zimmermanae*) are known from the Amazonian lowlands (<1000 m; see IUCN et al., 2004).

## DISCUSSION

### *Neglect of Canopy in Amphibian Inventories?*

Most amphibian inventories in tropical rainforests are carried out at ground level, typically along shallow strata (only ~2 m), characterized by higher humidity and lower ambient temperature than other microhabitats. Therefore, accounts of the diversity, community composition, and abundance of amphibians in these structurally complex forests are biased toward a relatively localized environmental space. *Eleutherodactylus aureolineatus* and other members of the *lacrimosus* assemblage are good examples of species that can be overlooked as a consequence of microhabitat sampling bias.

This bias could be influential in inventories on which visual encounter surveys (VES), transect surveys, or quadrats are the predominant sampling methods. An example is given by inventories carried out in the YSRS and at the TBS. At the YSRS, between 1995 and 2003, a total of 1540 specimens, belonging to 72 amphibian species, have been

collected (QCAZ database). Despite the large sampling effort, only one *E. aureolineatus* (QCAZ 19534) has ever been collected below the canopy. The only additional *E. aureolineatus* known from this locality (QCAZ 20712–13) were collected during sporadic canopy searches (especially in tank bromeliads) carried out during one week in May 2002.

At the TBS, between 1998 and 2001, almost 600 specimens, belonging to 87 species of amphibians were collected (Cisneros-Heredia 2003, D. F. Cisneros-Heredia, unpublished data). All paratypes (except for one juvenile found near the floor, DFCH-USFQ 0559) were collected in the canopy. Aside from the type series, nine additional specimens were also collected during the yearly canopy surveys (these specimens were not preserved). Also, *E. aureolineatus* seems to be an abundant species in the canopy; bromeliad patch sampling of 40 bromeliads among eight trees resulted in the collection of eight specimens.

The specimens of *Eleutherodactylus aureolineatus* from the YSRS represent 13% of the total number found in the canopy searches, and the specimens from the TBS represent 27%. These results suggest that *E. aureolineatus* is a proportionally more abundant anuran within higher strata of the forest. In addition, at YSRS, the canopy searches yielded 13 specimens belonging to 6 species: *Dendrobates* aff. *ventrimaculatus*, *Nyctimantis rugiceps*, *Osteocephalus deridens*, *O. fuscifacies*, *O. planiceps*, and *Phrynohyas resinifictrix*. At the TBS, the canopy searches yielded 32 records belonging to 13 species: *Hyalinobatrachium munozororum*, *Cochranella* sp., *Dendrobates ventrimaculatus*, *D. duellmani*, *Eleutherodactylus lacrimosus*, *Gastrotheca longipes*, *Nyctimantis rugiceps*, *Osteocephalus deridens*, *O. planiceps*, *O. taurinus*, *Phrynohyas coriacea*, *P. resinifictrix*, and *Sphaenorhynchus carneus*. Bromeliad patch sampling yielded 11 specimens belonging to two additional species: *Dendrobates ventrimaculatus* and *Eleutherodactylus* sp. Similarly to *E. aureolineatus*, all these species found in canopy situation have been extremely rare during VES, and three (*Osteocephalus deridens*, *O. fuscifacies*, *Dendrobates duellmani*) were undescribed until recently (Jungfer et al., 2000; Schulte, 1999); the scarcity of these

species in herpetological collections is likely an artifact of survey methodology.

Although our sampling effort was limited, the results are consistent with the suggestion that canopy surveys can improve species richness assessments and inventory efficiency in tropical rainforests (e.g., Longino and Colwel, 1997; Kalko and Handley, 2001). Sampling methodologies that distribute capture effort more evenly among vertical strata of rainforests have the potential to enhance significantly our understanding of tropical amphibian communities.

*Acknowledgments.*—For comments on this manuscript, we thank R. Brown. Fieldwork at Yasuní was assisted by I. G. Tapia. Access to KU and TCWC specimens was provided by L. Trueb and L. Fitzgerald, respectively. Loans from QCAZ were arranged by L. A. Coloma. Research by JMG is partially supported by The University of Kansas, Fundación Numashir para la Conservación de Ecosistemas Amenazados, and a fellowship from the Fundación para la Ciencia y Tecnología del Ecuador (FUNDACYT) under the sponsorship of the Departamento de Ciencias Biológicas of the Pontificia Universidad Católica del Ecuador. Research by DFCH was partially supported by Universidad San Francisco de Quito, Tiputini Biodiversity Station, the 2002 Research Training Program, National Museum of Natural History, Smithsonian Institution, Smithsonian Women's Committee, and Ma. Elena and L. Heredia. Research by SFM is partially supported by Texas State University – Department of Biology and the TADPOLE Organization.

#### LITERATURE CITED

- AMPHIBIAWEB. 2005. AmphibiaWeb: Information on amphibian biology and conservation. Berkeley, California. Available at: <<http://amphibiaweb.org/>>. Accessed on 25 November 2005.
- CISNEROS-HEREDIA, D. F. 2003. Herpetofauna de la Estación de Biodiversidad Tiputini, Amazonía Ecuatoriana. En: De la Torre, S. y G. Reck. (Eds.). *Ecología y Ambiente en el Ecuador: Memorias del I Congreso de Ecología y Ambiente*. CD. Universidad San Francisco de Quito. Quito, Ecuador.
- DUELLMAN, W. E. 1978a. Three new species of *Eleutherodactylus* from Amazonian Perú (Amphibia: Anura: Leptodactylidae). *Herpetologica* 34:264–270.
- . 1978b. The biology of an Equatorial herpetofauna in Amazonian Ecuador. The University of Kansas Museum of Natural History, Miscellaneous Publications 65:1–352.
- . 1990. A new species of *Eleutherodactylus* from the Andes of northern Peru (Anura: Leptodactylidae). *Journal of Herpetology* 24:348–350.
- GUAYASAMIN, J. M. 2004. A new species of *Eleutherodactylus* (Anura: Leptodactylidae) from the northwestern lowlands of Ecuador. *Herpetologica* 60: 103–116.
- HEYER, W. R., AND L. M. HARDY. 1991. A new species of frog of the *Eleutherodactylus lacrimosus* assembly from Amazonia, South America (Amphibia: Anura: Leptodactylidae) from the northwestern lowlands of Ecuador. *Proceedings of the Biological Society of Washington* 104:436–447.
- IUCN, Conservation International, and NatureServe. 2004. *Global Amphibian Assessment*. Available at: <http://www.globalamphibians.org>. Accessed on 21 October 2005.
- JUNGFER, K. S., R. RON, R. SEIPP, A. ALMENDÁRIZ, AND G. KÖHLER. 2000. Two new species of hylid frogs, genus *Osteocephalus*, from Amazonian Ecuador. *Amphibia & Reptilia* 21:327–340.
- KALKO, E. K. V., AND C. O. HANDLEY. 2001. Neotropical bats in the canopy: diversity, community structure, and implications for conservation. *Plant Ecology* 153: 319–333.
- KÖHLER, J., V. R. MORALES, S. LÖTTERS, S. REICHLER, AND J. APARICIO. 1998. A new green frog, genus *Eleutherodactylus*, from Bolivia and Perú (Amphibia, Anura, Leptodactylidae). *Studies on Neotropical Fauna & Environment* 33:93–99.
- LONGINO, J. T., AND R. K. COLWELL. 1997. Biodiversity assessment using structured inventory: capturing the ant fauna of a tropical rainforest. *Ecological Applications* 7:1263–1277.
- LYNCH, J. D. 1978. A new *Eleutherodactylus* frog from the Andes of northern Colombia (Leptodactylidae). *Copeia* 1978:17–21.
- . 1979. Leptodactylid frogs of the genus *Eleutherodactylus* from the Andes of southern Ecuador. The University of Kansas Museum of Natural History, Miscellaneous Publications 66:1–62.
- . 1981. Two new species of *Eleutherodactylus* from western Colombia (Amphibia: Anura: Leptodactylidae). University of Michigan, Occasional Papers of the Museum of Zoology 697:1–12.
- LYNCH, J. D., AND W. E. DUELLMAN. 1980. The *Eleutherodactylus* of the Amazonian slopes of the Ecuadorian Andes (Anura: Leptodactylidae). The University of Kansas Museum of Natural History, Miscellaneous Publications 69:1–86.
- . 1997. Frogs of the genus *Eleutherodactylus* (Anura: Leptodactylidae) in western Ecuador: systematics, ecology, and biogeography. The University of Kansas Natural History Museum Special Publication 23: 1–236.
- LYNCH, J. D., AND P. M. RUÍZ-CARRANZA. 1985. A synopsis of the frogs of the genus *Eleutherodactylus* from the Sierra Nevada de Santa Marta, Colombia. Occasional Papers of the Museum of Zoology, University of Michigan 711:1–59.
- PALACIOS, W., C. CERÓN, R. VALENCIA, AND R. SIERRA. 1999. Las formaciones naturales de la Costa del Ecuador. Pp. 109–119. In R. Sierra (Ed.), *Propuesta Preliminar de Clasificación de Vegetación para el Ecuador Continental*. Proyecto INEFAN/GEF-BIRF and EcoCiencia, Quito, Ecuador.
- READ, M. 2000. Frogs of the Ecuadorian Amazon: a guide to their calls. Compact Disc. Morley Read Productions, Fowey, Cornwall, U. K.
- RIVERO, J. A., AND M. A. SERNA. 1988 “1987”. Tres nuevas especies de *Eleutherodactylus* (Amphibia: Leptodactylidae)

de Antioquia, Colombia. *Caribbean Journal of Sciences* 23:386–399.

- RON, S. R. 2001. Anfibios del Parque Nacional Yasuní, Amazonía ecuatoriana. [on line]. Ver. 1.3 (2 Marzo 2001). Museo de Zoología, Pontificia Universidad Católica del Ecuador. Quito, Ecuador. Available at: <http://www.bio.utexas.edu/grad/ecuador/web/yasuni/esp/anfyas.htm>. Accessed on 10 October 2005.
- SCHULTE, R. 1999. Pfeilgiftfrösche, Artenteil—Peru. Nikola. Stuttgart, Germany.
- TORRES-CARVAJAL, O. 2005. A new species of iguanian lizard (*Stenocercus*) from the western lowlands of southern Ecuador and northern Peru. *Herpetologica* 61:75–85.

Accepted: 19 December 2005

Associate Editor: Joseph Mendelson

## APPENDIX I

### Specimens Examined

*Eleutherodactylus apiculatus* (KU 212534–38, paratypes). *Eleutherodactylus boulengeri* (KU 169056–61, paratypes). *Eleutherodactylus brevifrons* (KU 169006–13, paratypes). *Eleutherodactylus bromeliaceus* (KU 174524–25, paratypes). *Eleutherodactylus eremitus* (KU 140878, 179085–86; paratypes). *Eleutherodactylus lacrimosus* (KU 110782, neotype; 148889–908, 123391–98, DFCH-USFQ D50). *Eleutherodactylus mendax* (KU 173234, holotype; 171897, paratype). *Eleutherodactylus petersorum* (KU 143508, holotype). *Eleutherodactylus prolixodiscus* (KU 132727–33, paratypes). *Eleutherodactylus schultei* (KU 209498–504, paratypes).

*Herpetologica*, 62(2), 2006, 202–220  
© 2006 by The Herpetologists' League, Inc.

## THREE NEW SPECIES OF *COPHIXALUS* (ANURA: MICROHYLIDAE) FROM SOUTHEASTERN NEW GUINEA

FRED KRAUS<sup>1,2</sup> AND ALLEN ALLISON<sup>1</sup>

<sup>1</sup>*Bernice P. Bishop Museum, 1525 Bernice Street, Honolulu, HI 96817, USA*

**ABSTRACT:** We describe three new species of a cryptic species complex of *Cophixalus* from southeastern New Guinea and adjacent islands. They are readily distinguished from all other Papuan species by their small size, presence of vocal slits in males, absence of toe webbing, relatively long legs, short snouts, and vertical lores. Their calls consist of a series of high-pitched peeps. Intraspecific color pattern is highly variable and variant patterns are shared among species. Members of this complex can be distinguished from each other on the basis of adult body size, extent of development of the first finger and disc, snout width, tympanum size, and advertisement calls. The new species are among the most common frogs where found. Two of the species are currently known only from their type localities, but the third ranges more broadly in the Southeast Peninsula of New Guinea and D'Entrecasteaux Islands.

*Key words:* Anura; *Cophixalus*; Microhylidae; New Guinea; New species

IN THE COURSE of conducting herpetological surveys in Milne Bay Province, Papua New Guinea, during 2002, we found an undescribed species of *Cophixalus* to be among the most common components of the anuran community at a number of locations. It has been known for approximately 30 years and was featured in Menzies (1975:pl. 12C) but has not received a name or formal description. Menzies (1975:60) further noted that a second, similar species might replace this species at higher elevations. In expanding our initial surveys to

additional localities, apparent differences in call parameters lent support to Menzies' supposition that more than one species was involved, although morphologically they are virtually impossible to tell apart in the field. Additional collections and recordings of similar animals from Central Province made it clear that the situation was more complicated than suggested by Menzies. It is now apparent that the frog referred to as "*Cophixalus* species" by Menzies (1975:59–60) is actually a complex of cryptic species. Here we describe three of these species but note that additional members may remain to be discovered. This brings the

<sup>2</sup> CORRESPONDENCE: e-mail, [fkraus@hawaii.edu](mailto:fkraus@hawaii.edu)