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Notes on Geographic Distribution

Distribution extension for *Anolis salvini* Boulenger, 1885 (Reptilia: Squamata: Dactyloidae), in western Panama

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Abstract: We report new localities for the lizard *Anolis salvini* Boulenger, 1885, along the Pacific slopes of the Cordillera Central in Chiriquí province and the Comarca Ngöbe-Buglé of western Panama. These records extend the known geographic distribution of this species about 70 km eastwards. They also extend the known vertical distribution approximately 70 m uphill. Additionally, we provide the first record for the Caribbean slopes, an updated distribution map, photos of specimens from different localities, an analysis of a distress call, and comments on the morphology of this species.

Boulenger (1885) described *Anolis salvini* on the basis of a single male specimen (holotype by monotypy, now BMNH 1946.9.8.19) from "Guatemala", where the species has not been recorded since (Köhler 2007). Almost 90 years later, Myers (1971) described *A. vociferans* based on eight types from the Talamancan highlands in Panama and Costa Rica. Köhler (2007) judged the types of both nominal taxa to be conspecific, pointed out possible mixups in locality data underlying Boulenger's original description, and accordingly placed *A. vociferans* in the synonymy of *A. salvini*. However, neither Sasa *et al.* (2010) nor Jaramillo *et al.* (2010) followed this decision and listed the species as *A. vociferans.* This short-legged anole is known from premontane and lower montane elevations between 1100 and 1980 m asl along the Pacific versant of the Cordillera de Talamanca of Costa Rica and Panama (Myers 1971; Savage 2002; Köhler 2008; Jaramillo *et al.* 2010; Lotzkat *et al.* 2010). Little is known about the natural history of *A. salvini* except for its arboreal habits and its ability to vocalize. During field-work in the highlands of western Panama and eastern Costa Rica between 2006 and 2010, we collected 28 additional specimens of *A. salvini* from different localities that considerably improve our knowledge of the distribution and morphological variation of this species.

All specimens were encountered during opportunistic searches performed primarily at night, caught by hand, and preserved the day after capture. The distress call of one individual could be recorded using a M-Audio Microtrack II solid state recorder and a Hama RMZ-10 Zoom Universal directional microphone. Calls were recorded in PCM format at a sampling rate of 48 kHz with 24 bit resolution and stored as wav files on a CF Card. Call editing and analysis were performed using Sound Ruler 0.9.6.0 (Gridi-Papp 2007) for frequency analysis and to generate figures of oscillograms and audiospectrograms. We measured temporal parameters by hand using Adobe Audition 3.0. For Panama, the collecting permits SC/A-20-05, SE/A-30-08, SC/A-8-09, SC/A-28-09 and SC/A-21-10, as well as the corresponding exportation permits, were issued by the Dirección de Áreas Protegidas y Vida Silvestre of the Autoridad Nacional del Ambiente (ANAM), Panama City, Panama. For Costa Rica, the collecting permit 002-2010-SINAC was issued by the Ministerio de Ambiente, Energía y Telecomunicaciones (MINAET), San José, Costa Rica.

A list of all specimens examined in this work is provided in the Appendix. Specimens collected by us have been deposited in the herpetological collection of the Senckenberg Forschungsinstitut Frankfurt, Frankfurt am Main, Germany (SMF), and in the Museo Herpetológico de Chiriquí, Davíd, Chiriquí, Panama (MHCH). Species identification was carried out employing the keys, figures, and descriptions provided by Köhler (2007, 2008). Adult specimens were sexed by evertion of hemipenes and juveniles by presence (males) or absence (females) of enlarged postcloacal scales (Myers 1971; Köhler 2007, 2008, 2010). Characters of external morphology were recorded according to the methodology described by Köhler *et al.* (2007). The capitalized colors and color codes (the latter in parentheses) are those of Smithe (1975–1981).

Geographic coordinates and altitude above sea level were recorded with Garmin GPS receivers with integrated barometric altimeter. All georeferences are in geographical coordinate system and WGS 1984 datum. Elevations are rounded to the next tenth. The map was created using ArcGIS 10 (ESRI) and the NASA elevation datasets processed by Jarvis *et al.* (2008). For other distributional records of *Anolis salvini*, we consulted relevant literature (Myers 1971; de Sousa 1999; Köhler 2007) and directly searched the catalogues of the Museo de Vertebrados de la Universidad de Panamá (MVUP), SMF and the Círculo Herpetológico de Panamá (CHP; accessed through the GBIF data portal, http://ara.inbio.ac.cr/SSTN-IABIN/datasets/resource/37, 2011-11). Additional data were obtained from records held in the following institutions and accessed through the HerpNET data portal (http://

www.herpnet.org) on 15 November 2011 (Collection acronyms follow Sabaj Pérez 2010): ANSP, CAS, and FMNH.

De Sousa (1999) reported *Anolis salvini* (as *Norops vociferans*) from the surroundings of the Fortuna dam site. The corresponding specimen MVUP 799 from "Loma del silencio, prov. Chiriquí", catalogued as *Anolis vociferus* (sic) was examined by SL and found to represent *A. charlesmyersi* Köhler, 2010. Thus, no reproducible record of *A. salvini* exists from the Fortuna area.

The map (Figure 1) shows the type locality of *Anolis vociferans*, locality records from the references mentioned above, and the localities reported herein. From west to east, we provide the following new records for *A. salvini* (see Appendix for coordinates and altitude).

One juvenile specimen was collected at Las Tablas, Puntarenas Province, Costa Rica (Figure 1, locality 1). A total of nine specimens were collected in Jurutungo (locality 2), the high valley of the Río Candela in the Parque International La Amistad (PILA), Chiriquí Province, Panama. In addition, we observed eight more specimens during field trips at this locality. Five specimens were taken in the area around the street from the city of Volcán to Cerro Punta, next to Bambito, Chiriquí Province, Panama (locality 3). Six specimens were encountered in an accumulation of almost a dozen conifers, at Cerro Altrillería, the mountain range next to Alto Jaramillo, Chiriquí Province, Panama (locality 4). We observed five additional specimens at this locality. Along the banks of Quebrada Juglí on the southeastern slopes of Cerro Saguí (also known as Cerro Ratón; locality 5) Comarca Ngöbe-Buglé, Panama, we secured four individuals, and in addition observed two other specimens. The easternmost specimens were collected nearby in a corn field above the settlement Ratón, Comarca Ngöbe-Buglé, Panama (locality 6), where one additional specimen also was observed. Our specimens came from different habitats (Figure 3) ranging from small bushes and trees in agricultural area and plantations, through secondary forest, to elfin forest. All individuals were encountered at night, sleeping on vegetation between 0.5 and 5 m above ground.

Our findings extend the known geographic range of *Anolis salvini* eastward as well as uphill. The adult female SMF 90169, collected on Cerro Altrillería at 2050 m asl, extends the known elevational distribution of the species 70 m upward, followed by the specimens collected in Jurutungo at 2000 m asl (Lotzkat *et al.* 2010). The localities in the surroundings of Cerro Saguí, approximately 70 km east of the previously easternmost reported localities near Boquete (ZMFK fide Köhler 2007; CAS; CHP), now constitute the easternmost records reported for the species, extending its distribution into the Serranía de Tabasará and the Comarca Ngöbe-Buglé. Here, the findings at Quebrada Juglí also are the first records for the Caribbean drainage of the Costa Rican and Panamanian mountain ranges. With an area of approximately 3000 ha above 2000 m asl, Cerro Saguí is the most impressive massif of the Serranía de Tabasará and still very little explored. Besides this record, the tree frog *Isthmohyla picadoi*, also assumed to be an endemic of the Cordillera de Talamanca previously, has been recorded from Cerro Saguí in the course of this project (Hertz and Lotzkat 2012). We propose that with ongoing investigation more Talamancan highland species will be discovered at this site.

Considering all collecting sites, the known distributional range of *Anolis salvini* stretches over approximately 230 km from roughly 83°40'W in the Cordillera de Talamanca of eastern Costa Rica to 81°49'W in the Serranía de Tabasará of western Panama, chiefly along the Pacific drainage at

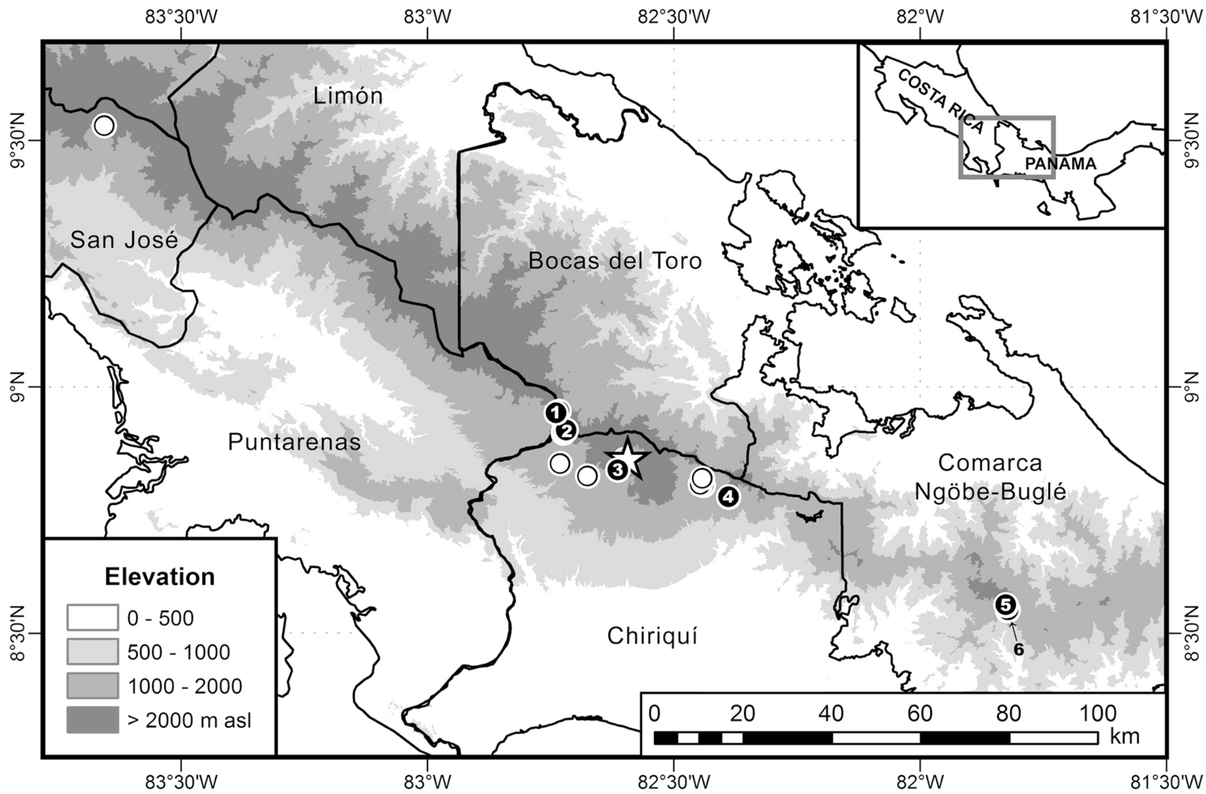

Figure 1. Distribution map showing the known localities for *Anolis salvini* in Costa Rica and Panama: The white star represents the type locality of *A. vociferans*, white circles the records from literature and databases, black circles the localities reported herein. See text for details.

elevations between 1100 and 2050 m asl. Future field work will most probably expand the horizontal and vertical distribution farther.

Selected specimens are shown in Figure 2. The examination of our additional specimens allows for a more comprehensive assessment of the variation in external morphology. In Table 1, we provide selected morphological characteristics of *Anolis salvini,* based on all our specimens (n=28). Our specimens show the diagnostic morphological characters provided by Myers (1971) and

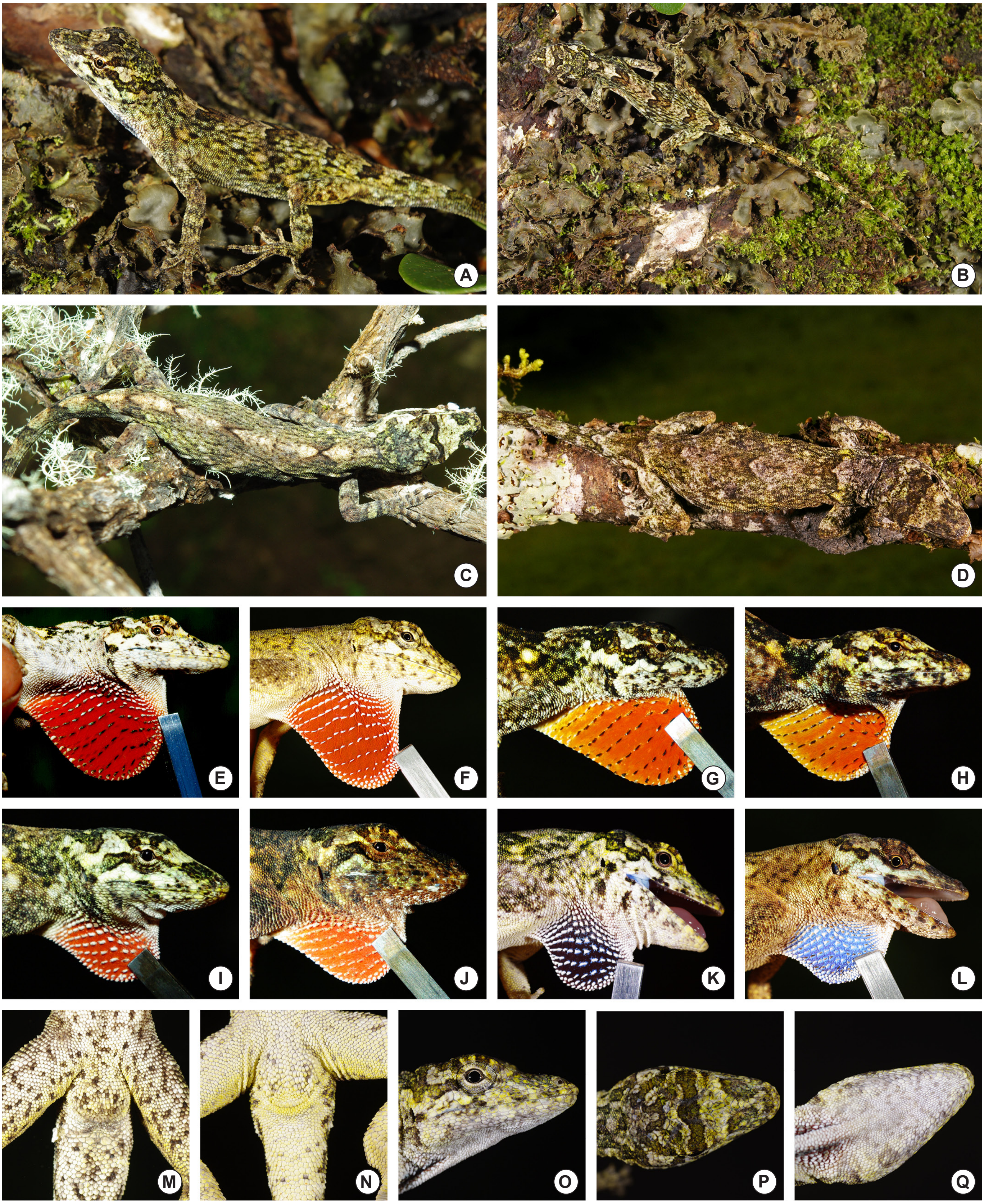

Figure 2. Individuals of *Anolis salvini* from different localities in Panama: (A–B) male SMF 91528 from Quebrada Juglí; (C) female MHCH 2288 from Alto Jaramillo; (D) female SMF 89527 from Jurutungo; (E–H) male dewlaps: (E) SMF 85451 from Jurutungo; (F) SMF 91526 from Quebrada Juglí; (G) SMF 90168 from Alto Jaramillo; (H) SMF 90167 from Alto Jaramillo; (I–L) female dewlaps: (I) MHCH 2288; (J) MHCH 2289 from Alto Jaramillo; (K) MHCH 2291 from Jurutungo; (L) SMF 91523 from Ratón; (M–N) cloacal region: (M) male MHCH 2293 from Quebrada Juglí; (N) female MHCH 2291 from Jurutungo; (O–Q) head: SMF 89758 from Jurutungo; (O) lateral, (P) dorsal, (Q) ventral view.

Köhler (2007), except for the ventrals actually being slightly keeled in all specimens, and could be identified using the keys of Savage (2002) or Köhler (2008). In conclusion, *A. salvini* is distinguishable from all other anoles by the following combination of characteristics: an overall lichenous coloration, a dark butterfly-shaped marking across the dorsal base of tail, black throat lining, dark interorbital bar, bright blue-silver colored mouth corners, very short legs (tip of the fourth toe reaching to somewhere between shoulder and ear when extended hind limb is adpressed along the straightened specimen), a relatively short tail (less than 1.5 times SVL), fewer than 40 loreals in fewer than 5 horizontal rows, the presence of enlarged postcloacal scales in males, and at least slightly keeled ventral scales.

It is noteworthy that both sexes exhibit a high variability in their dewlap coloration: From light-blue to purple-red in females, and from yellow-orange to brick red in males. In recent literature, the dewlap scales were described as white (Savage 2002; Köhler 2007; 2008). However, we are unable to confirm this morphological character, because *A. salvini* is capable of metachrosis involving the dewlap scales, and we observed black, gray, as well as white dewlap scales, even in the same individual (compare Figures 2 E–L).

The coloration in life of an adult female (SMF 89527; Figure 2 D) was recorded as follows: Dorsal ground color Smoke Gray (44), grading into Drab-Gray (119D) laterally; dorsal and lateral surfaces with dense Brownish Olive (29) mottling and some diffuse Opaline Green (162D) and Chamois (123D) flecks; interorbital stripe and snout Sepia (219) suffused with Army Brown (219B); ventral surfaces dirty white with a suggestion of Pearl Gray (81) with Light Drab (119C) spots; dorsal and lateral surfaces of tail with a series of diffuse Sepia (119) transverse bands suffused with Light Neutral Gray (85) and Pearl Gray (81); iris Raw Umber (123); dewlap dirty white at posterior and anterior bases, with a Purple (1) free margin suffused with Mauve (172C) anteriorly, grading into Royal Purple (172A) towards apex; dewlap scales dirty white. The dewlap coloration in life of an adult male (SMF 89758) was recorded as follows: Spectrum Red (11), with dirty white and Blackish Neutral Gray (82) scales. The dewlap coloration in life of a juvenile male (SMF 89756) was recorded as follows: Crimson (108), with most marginals, sternals, and gorgetals dirty white, and some sternals and gorgetals Sepia (119). The dewlap coloration in life of a juvenile female (SMF 89757) was recorded as follows: Royal Purple (172A), with dirty white scales.

The vocalization can be characterized as a distress call, thus it is emitted when the animal is captured or handled. The recorded vocalization of SMF 90167 is a loud squeak that lasts about 1.9 s. It is strongly pulsed with a mean pulse rate of approximately 130 pulses/s and contains distinct harmonics. The dominant frequency of pulses varies from 3070-3450 Hz (3180±120 Hz) and there is no evident frequency modulation in a single pulse (Figure 4).

Both sexes of *Anolis salvini* have the ability to emit a distress sound when molested. Vocalization could most easily be initiated when catching sleeping individuals from their resting position at night. In day-time, annoyance had to be heavier to provoke vocalization. Crowley and

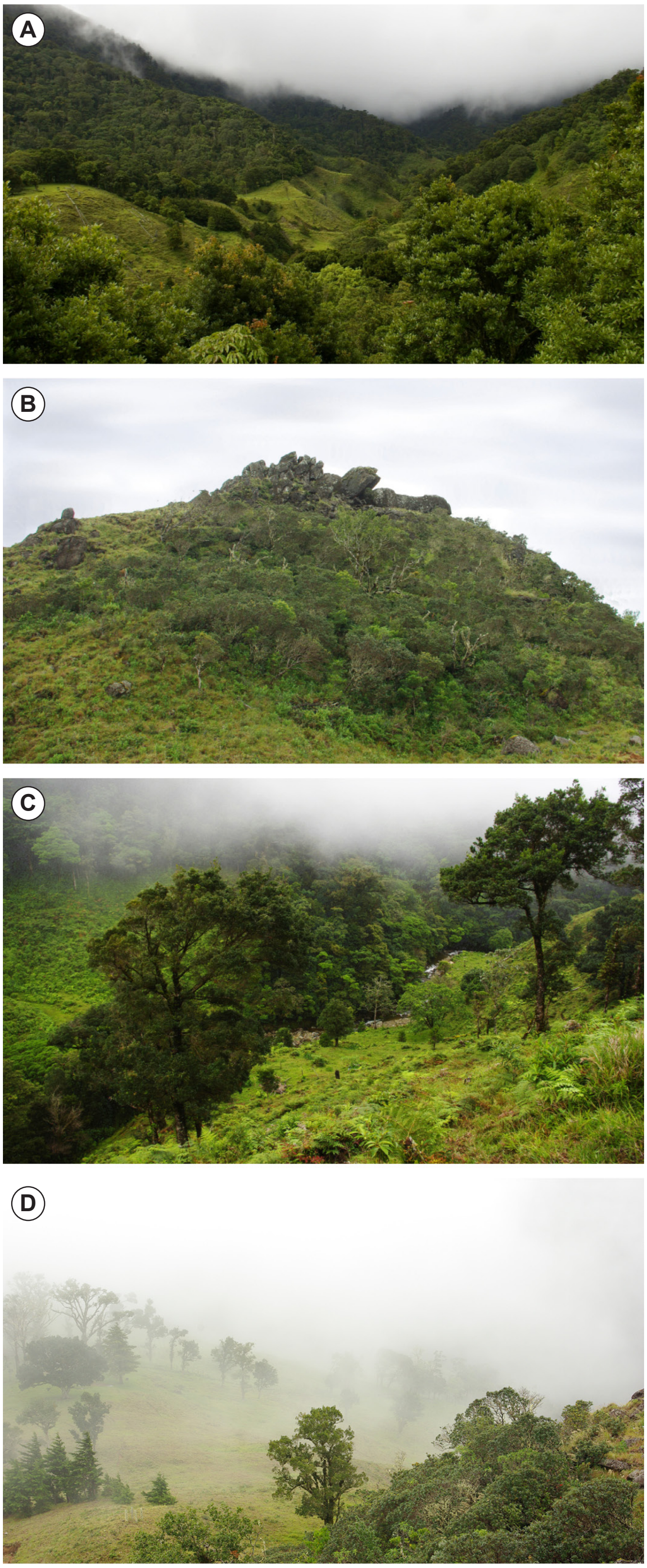

Figure 3. Different habitats of *Anolis salvini* in western Panama: (A) mosaic of pasture and forest at Jurutungo, ca. 2000 m asl; (B) isolated patch of elfin forest at Alto Jaramillo, ca. 2050 m asl; (C) pasture at Quebrada Juglí, ca. 1700 m asl; (D) agricultural area at Alto Jaramillo, ca. 2000 m asl.

Pietruszka (1983) could link occurrence of distress sounds in the leopard lizard (*Gambelia wislizenii*) with body temperature. At high body temperatures, the lizard preferred to flee, while at low body temperatures, when the ability to escape is retarded, a defense behavior consisting of vocalizations, aggressive postures, and attacks predominated. *Anolis salvini* inhabits intermediate elevations to more than 2000 m asl, where temperature easily drops below 15°C at night. Albeit the most important predators for sleeping anoles are arthropods (McCormick and Polis 1982; Clark and Gillingham 1990), which should not be deterred from attacking by a prey's distress sounds. Milton and Jenssen (1979) could not identify a correlation between the ability of different anoles to vocalize and their phylogenetic relationship, geographic distribution, or habitat preference. However, taking in account that distress-related vocalization has apparently evolved various times in anoles, there should be an evolutionary benefit derived from it. Further studies should investigate what exactly it is that vocalizing anoles have in common and why vocalization evolved in certain species of anoles, apart from how many more species of this group might be able to produce sounds than those about which we know.

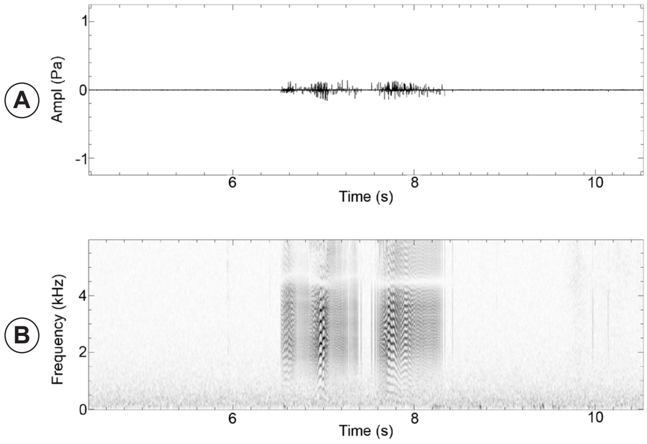

Figure 4. Distress call of *Anolis salvini* from western Panama (SMF 90167), (A) Oscillogram and (B) Spectrogram.

Table 1. Selected measurements, proportions, and scale characters of 12 males and 16 females (n=28) of *Anolis salvini*. Range is followed by mean value and standard deviation in parentheses.

CHARACTER	SEX	VALUE
Snout-vent length	males	36–61 (52.7 ± 6.3)
	females	33–66 (55.6 ± 7.6)
Tail length	males (n=9)	44–81 (67.8 ± 10.1)
	females (n=12)	37–81 (67.8 ± 11.7)
Tail length / Snout-vent length	males (n=9)	1.22–1.45 (1.31 ± 0.07)
	females (n=12)	1.12–1.37 (1.24 ± 0.07)
Tail diameter vertical / horizontal	males (n=9)	1.1–1.46 (1.3 ± 0.13)
	females(n=12)	1.04–1.5 (1.29 ± 0.13)
Axilla-groin distance / Snout-vent length	males	0.4–0.44 (0.42 ± 0.01)
	females	0.39–0.47 (0.43 ± 0.02)
Head length / Snout-vent length	males	0.25–0.27 (0.26 ± 0.01)
	females	0.24–0.27 (0.26 ± 0.01)
Head length / Head width	males	1.38–1.59 (1.48 ± 0.06)
	females	1.38–1.62 (1.51 ± 0.06)
Shank length / Snout-vent length	males	0.15–0.19 (0.18 ± 0.01)
	females	0.16–0.19 (0.17 ± 0.01)
Shank length	males	6.1–10.8 (9.3 ± 1.2)
	females	5.6–11 (9.5 ± 1.2)
Subdigital lamellae under phalanges II–IV of 4th toe		25–34 (29.2 ± 2)
Number of scales between supraocular semicircles		0–1 (0.5 ± 0.5)
Number of scales between interparietal and supraocular semicircles		1–3 (1.6 ± 0.6)
Number of scales between suboculars and supralabials		0
Number of supralabials to level below center of eye		6–8 (7 ± 0.6)
Number of infralabials to level below center of eye		5–8 (6.7 ± 0.7)
Total number of loreals		12–39 (21.1 ± 5.9)
Number of horizontal loreal scale rows		2–4 (2.9 ± 0.5)
Number of postrostrals		5–9 (6.3 ± 1.1)
Number of postmentals		4–9 (5.9 ± 1.7)
Number of scales between nasals		5–7 (5.8 ± 0.7)
Number of scales between 2nd canthals		4–7 (5.7 ± 0.9)
Number of scales between posterior canthals		5–9 (7.1 ± 1.1)
Number of medial dorsal scales in one head length		20–46 (37.4 ± 5.3)
Number of medial ventral scales in one head length		20–58 (44.8 ± 7.2)
Scales around midbody		106–142 (125.4 ± 9.4)

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Appendix 1. Comparative material examined; localities from west to east.

Anolis charlesmyersi.— **Panama:** Chiriquí: Reserva Forestal La Fortuna: Loma del Silencio: MVUP 799 (catalogued as "*Anolis vociferus*").

Anolis salvini.— **Costa Rica:** Puntarenas: Las Tablas, 8°56'50" N, 82°44'21" W, 1860 m: SMF 92510; **Panama:** Chiriquí: PILA: Jurutungo, 8°54'43" N, 82°43'60" W, 1980 m: SMF 89527; Jurutungo, 8°54'22" N, 82°43'27" W, 1900 m: SMF 89755; Jurutungo, Finca P. Yangüez: 8°54'38" N, 82°43'23" W, 2000 m: SMF 89757, 89758, MHCH 2290, 2291; Jurutungo, 8°54'31" N, 82°43'22" W, 1860 m: SMF 85451, 85452; Jurutungo, 8°54'25" N, 82°43'22" W, 1950 m: SMF 89756; Cerro Pelota, 8°49'51" N, 82°36'50" W, 1580–1640 m: SMF 85453–85457; Alto Jaramillo, Cerro Altrillería, 8°46'36" N, 82°23'20" W, 1990 m: SMF 90167, 90168, MHCH 2287, 2288, 2289; Cerro Altrillería, 8°46'33" N, 82°23'19" W, 2050 m: SMF 90169; Comarca Ngöbe-Buglé: Quebrada Juglí, 8°33'27" N, 81°49'34" W, 1710 m: SMF 91527, 91528, MHCH 2293; Quebrada Juglí, 8°33'22" N, 81°49'31" W, 1700 m: SMF 91526; Above Ratón, grazing field, 8°32'46" N, 81°49'21" W, 1640 m: SMF 91525; Above Ratón, corn plantation, 8°32'48" N, 81°49'18" W, 1680 m: SMF 91523, MHCH 2292; Above Ratón, corn plantation, 8°32'50" N, 81°49'16" W, 1730 m: SMF 91524.