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First Record of the Greenhouse Frog *Eleutherodactylus planirostris* (Anura, Eleutherodactylidae) from San Andrés, Colombian Caribbean Islands

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ABSTRACT—We report for the first time the greenhouse frog *Eleutherodactylus planirostris* from San Andrés, the largest Colombian Caribbean island. This record represents the second known frog species on the island, and the second invasive *Eleutherodactylus* species reported from Colombian territory. In addition, we describe and discuss the morphology and some aspects of the natural history of this newly documented and well-established population. Additional research about the ecological impacts of invasion of *E. planirostris* on natural ecosystems and native species of San Andrés are required.

RESUMEN—Reportamos por primera vez la rana de invernadero *Eleutherodactylus planirostris* en San Andrés, la más grande de las islas Caribeñas colombianas. Este registro representa la segunda especie de rana conocida de la isla, y la segunda especie invasiva de *Eleutherodactylus* reportada de territorio colombiano. También describimos y discutimos la morfología y algunos aspectos de la historia natural de esta población recientemente documentada y bien establecida. Se requiere más investigación sobre los impactos

The Archipiélago of San Andrés, Providencia, and Santa Catalina (Colombian Caribbean islands) is part of the Western Caribbean, a Neotropical ecoregion with an endemic, complex, and highly diverse biota (Hedges et al. 2019). San Andrés island is the largest, most biodiverse, and most impacted by human activities among the Colombian Caribbean islands. The herpetofauna of San Andrés have been briefly documented, and there are reports of at least 18 terrestrial species (15 squamate reptiles, one freshwater turtle, one crocodilian, and one frog; Dunn 1945; Dunn and Saxe 1950; Tamsitt and Valdivieso 1963; Valdivieso and Tamsitt 1963; Scott and Ayala 1984; McNish 2011). An additional species, the red-footed tortoise *Chelonoidis carbonarius* (Spix, 1824) is also present on San Andrés, several individuals are maintained as pet and tourist attractions, although there is still no evidence of feral populations (pers. obs.).

According to the current evidence, *Gonatodes albogularis fuscus* (Hallowell, 1855), *Hemidactylus angulatus* Hallowell, 1854, *Hemidactylus frenatus* Duméril & Bibron, 1836, *Tretioscincus bifasciatus* (Duméril & Duméril, 1851), *Tupinambis* sp., *Boa imperator* Daudin, 1803, and *Caiman crocodilus fuscus*

(Cope, 1868) were purposely or indirectly introduced by humans from colonial to modern times (Scott and Ayala 1984; McNish 2011). Moreover, it is suspected, although without evidence, that the presence of *Iguana rhinolopha* (Wiegmann, 1834), *Ctenosaura similis* (Gray, 1831), *Kinosternon scorpioides albogulare* (Duméril & Bocourt, 1870), and *Leptodactylus insularum* Barbour, 1906, correspond to pre-Columbian introductions (Dunn 1945; Dunn and Saxe 1950). The implications of these introductions, plus the habitat loss due to human population growth and the response to the constant increase of the tourism demand in the region, are threat factors for native species, some of which are already considered threatened or near threatened (Caicedo-Portilla 2014; Morales-Betancourt et al. 2015).

The amphibians of the Colombian Caribbean islands are historically represented exclusively by populations of the mainland species *L. insularum* (Dunn 1945; Dunn and Saxe 1950; McNish 2001). However, in August 2018, numerous individuals of a small frog were found at the southern end of San Andrés, some of which were photographed but not identified, and some calls were also recorded. Based on the photograph records,

in early 2020 these frogs were again searched for on the island, and some individuals were collected. A detailed examination of the specimens and comparisons of the advertisement calls revealed that they correspond to the greenhouse frog *Eleutherodactylus planirostris* (Cope, 1862; Anura, Eleutherodactylidae).

Eleutherodactylus planirostris is native to Cuba, Bahamas, and the Cayman Islands (Heinicke et al. 2011), and has been introduced to other Caribbean islands, the continental United States, some Central American countries, some continental locations and islands of Asia and Africa, and some Pacific islands (Hawaii and Guam, Fig 1a). A detailed account and localities of introductions of that species is shown in CABI (2020). Here, we report the occurrence of *E. planirostris* on San Andrés and Colombia for the first time, with a morphological description, and comments on biological and ecological aspects.

MATERIALS AND METHODS

San Andrés (Fig. 1b, c) is a coral island located about 190 km from the eastern coast of Central America (Nicaragua), and 483 km from the northwestern coast of Colombia. This island is part of the dry tropical zonobiome (Hernández-Camacho and Sánchez 1992), with natural ecosystems of tropical dry and mangrove forests. The predominant vegetation coverage consists of shrubs, crops, and pastures, which surround small remnants of original forest coverage (Caicedo-Portilla 2014). The predominant climate is warm iso-megathermic and unimodal rainfall regime, with high rainfalls from May to November (Garay et al. 1988; Vargas-Cuervo 2004). Observations and collections of *E. planirostris* were conducted in 13 sites that cover almost the entire territory of San Andrés. The sites represented both natural and synanthropic habitats, including natural vegetation edges, natural and artificial water bodies, pastures, gardens, greenhouses, backyards, and even the interior of human constructions.

The first observation of *E. planirostris* was at Casa de las Flores in August 2018. Subsequently, 12 specimens were collected at Merrie Hill in January 2020. Observations and the collection of 11 additional specimens in the remaining sites were conducted between January 2020 to June 2021. Specimens were sacrificed using a topical lidocaine solution (10%) spread in the ventral surface and fixed in a formalin solution (10%). All vouchers were deposited at the Centro de Colecciones Científicas de la Universidad del Magdalena

(CBUMAG), Santa Marta, Colombia.

For taxonomic determination, we examined the morphological and morphometric characters proposed by Lynch and Duellman (1997) and Duellman and Lehr (2009), with the addition of two morphometric characters proposed by Tolosa et al. (2015). The following abbreviations were used: snout–vent length (SVL), head length (HL), head width (HW), internarial distance (ID), upper eyelid width (UEW), interorbital distance (IOD), eye distance (ED), eye-nostril length (ENL), tympanic diameter (TD), humeral length (HUL), forearm length (FOL), thigh length (THL), tibia length (TL), and foot length (FL).

The obtained combination of characters was compared with the descriptions provided by Schwartz (1974) and Díaz and Cádiz (2008). The dichotomous key for amphibians of northern Central America of Köhler (2011) was also used, as well as calls of related species provided by AmphibiaWeb (2020), and Alonso et al. (2007), from Fonoteca Zoológica [www.fonozoo.com], Museo Nacional de Ciencias Naturales (CSIC), Madrid, Spain. The taxonomic determination was confirmed by L. M. Díaz, Curator of Herpetology, Museo Nacional de Historia Natural de Cuba.

The examined specimens of *Eleutherodactylus planirostris* from Colombia are: ARCHIPIÉLAGO DE SAN ANDRÉS, PROVIDENCIA Y SANTA CATALINA: San Andrés isla: Punta Sur, Marrie Hill, CBUMAG:ANF:01174–85; Big Pond, CBUMAG:ANF:01186; Los Corales, CBUMAG:ANF:01187, CBUMAG:ANF:01191–94, CBUMAG:ANF:01195–98; Jardín Botánico de San Andrés, CBUMAG:ANF:01205.

RESULTS

Eleutherodactylus planirostris (Cope, 1862).

New record: Colombia, department of Archipiélago de San Andrés, Providencia y Santa Catalina; San Andrés island (Fig. 1c): Sarie Bay (12°35'26.7" N 81°42'09.4" W), El Bight (12°34'25.1" N, 81°42'38.2" W), Los Corales (12°33'41.6" N, 81°42'39.7" W), Old Point Mangrove Regional Park surroundings (12°33'40.2" N, 81°42'29.6" W), Jack Pond (12°33'05.2" N 81°43'07" W), Big Pond (12°32'55.3" N 81°43'12.4" W), Duppy Gully (12°32'23.0" N 81°43'16.3" W), Manuel Pond (12°32'06" N 81°43'14.6" W), Botanical Garden of San Andrés (12°32'12.6" N 81°42'39.5" W), Royal Palm Inn (12°30'59.9" N, 81°43'42.5" W), Elsy Bar (12°29'44.9" N, 81°43'43.7" W), Casa de las Flores

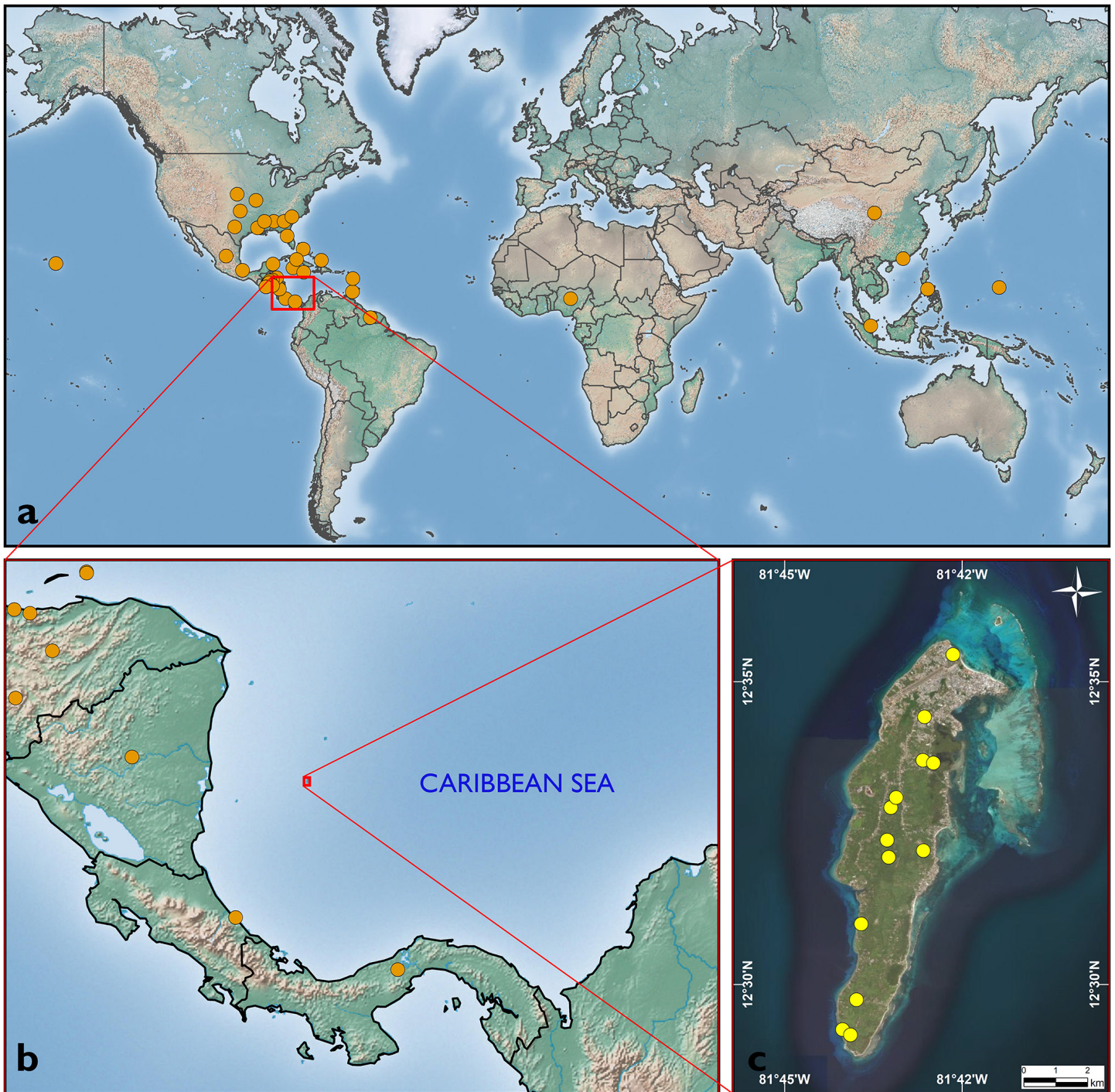


FIG. 1. Geographic distribution of *Eleutherodactylus planirostris*. Global distribution (a) (source: Cedeño-Vázquez et al. 2014; Barquero and Araya, 2016; Contreras-Calvario et al., 2018; CABI 2020; Antúnez-Fonseca 2021); location of San Andrés island (b), showing the localities (yellow dots) of the new record on the expanded area (c), from top to bottom: Sarie Bay, El Bight, Los Corales, Old Point, Jack Pond, Big Pond, Duppy Golly, Jardín Botánico, Manuel Pond, Royal Palm Inn, Elsy Bar, Casa de las Flores, and Merrie Hill.

(12°29'15.3" N, 81°44'01.4" W), and Merrie Hill (12°29'10.1" N, 81°43'53.4" W). This new record also represents the second frog inhabiting San Andrés island, and a new addition to the list of herpetofauna that has been introduced there.

Natural history

Individuals of *E. planirostris* (Fig. 2) are easily detected in both natural intervened and synanthropic habitats, occupying substrates such as grass, ornamental plants, under leaf litter, debris, logs, boulders, water

TABLE 1. Morphometric characters of specimens of *Eleutherodactylus planirostris* collected on San Andrés, Colombian Caribbean islands, Western Caribbean. Snout–vent length (SVL); head length (HL); head width (HW); internarial distance (ID); upper eyelid width (UEW); interorbital distance (IOD); eye distance (ED); eye-nostril length (ENL); tympanic diameter (TD); humeral length (HUL); forearm length (FOL); thigh length (THL); tibia length (TL); and foot length (FL). All characters are given in mm.

Character	CBUMAG:ANF numbers											
	01174	01175	01176	01177	01178	01179	01180	01181	01182	01183	01184	01185
SVL	22.2	23.2	18.3	17.9	16.0	21.0	15.4	20.7	20.5	14.9	15.4	16.4
HL	8.3	8.2	7.3	7.8	6.1	8.1	6.7	7.8	7.3	6.1	6.1	7.1
HW	7.3	7.1	6.5	6.6	5.9	7.0	5.0	7.2	7.0	4.6	4.9	5.8
IND	1.8	1.9	1.9	1.9	1.4	1.9	1.5	2.2	1.8	1.4	1.3	1.5
UEW	2.1	2.1	1.6	1.5	1.5	1.6	1.6	1.9	1.9	1.3	1.3	1.3
IOD	2.6	2.7	2.2	2.2	2.3	2.5	2.3	2.6	2.5	1.6	2.1	2.1
ED	2.8	2.6	2.2	2.4	2.6	2.9	2.6	2.7	2.4	1.8	1.8	1.8
ENL	2.4	2.5	2.4	2.9	2.2	2.4	2.1	2.6	2.4	1.6	2.0	1.6
TD	1.9	2.1	1.4	1.0	1.6	1.9	1.5	1.7	1.5	1.2	1.2	1.2
HUL	5.3	5.8	4.7	3.4	3.9	4.6	4.2	5.8	5.7	3.4	3.9	4.4
FAL	6.1	5.9	4.9	3.3	4.2	4.3	4.4	5.4	4.9	3.4	3.6	3.8
THL	10.2	10.2	9.5	7.7	7.2	9.3	8.2	9.2	8.6	6.0	6.2	7.6
TL	10.6	10.9	9.8	8.3	9.1	10.3	8.7	10.8	8.8	7.5	8.2	8.7
FL	11.3	10.9	9.6	8.5	8.2	10.0	7.6	10.4	8.8	6.9	8.0	8.5

reservoirs, and inside artificial structures (to a lesser extent). Specimens were recorded as being active at night, at least between 19:00–02:00 h, although sporadic vocalizations can be heard at anytime of the day. Thousands of individuals were detected in Jack Pond, a heavily sedimented seasonal water body, whose bed covered by abundant floating macrophytes (*Pistia stratioides*) is exposed in the dry season, providing an ideal microhabitat for frogs. In other localities such as Elsy Bar or the San Andrés Botanical Garden, greenhouse frogs are frequently found on edges of forest fragments or paths that cross through the fragments, but they are not found inside them.

On April 1, 2021, during field work in a pasture subject to permanent water leakage, an individual mass of 12 eggs was collected under a decayed coconut palm log about 20 m long (Fig. 3). Another three egg masses (with 16, 18, and 13 eggs) were collected in an adjacent smaller (about 2 m long) fallen log. All egg masses were found embedded in cracks in the log bark or moist soil. No parental care was detected in any of these egg masses. Nevertheless, on May 26, 2021, a male was observed performing parental care on a mass of six eggs deposited in the leaf litter at the bottom of a five-gallon bucket that was part of a pitfall trap system.

Taxonomic determination

Morphometric characters describing the population of *Eleutherodactylus planirostris* on San Andrés are summarized in Table 1. Specimens were determined as *E. planirostris* based on the following combination of characters: small size (maximum SVL = 23.2 mm), head short (HL/SVL = 35.28–43.66%) and longer than wide (HW/HL = 76.15–86.70%), snout truncated in lateral view, and subacuminated in dorsal view (IND/HW = 23.69–30.45%). Canthus rostralis straight and relatively short (ENL/HL = 26.48–36.35%). Upper eyelids wide (UEW/HW = 21.72–29.54%), relatively separated from each other (IOD/HW = 33.13–46.46%), with palpebral tubercles scarce and small. All remaining cephalic ornamentations such as tubercles, folds, and cranial crest are absent. Tympanum large and well defined (TD/ED = 69.88–81.39 %), with tympanic annulus and membrane present. Dentigerous processes of vomer in a transverse row posterior to the choanae, slightly separated from each other. Texture of dorsal skin shagreen and finely tuberculated. Dorsolateral folds are well defined and continuous from the posterior border of the back to the sacral area, more prominent on the sacrum. Lateral, suprascapular, middorsal, and paravertebral

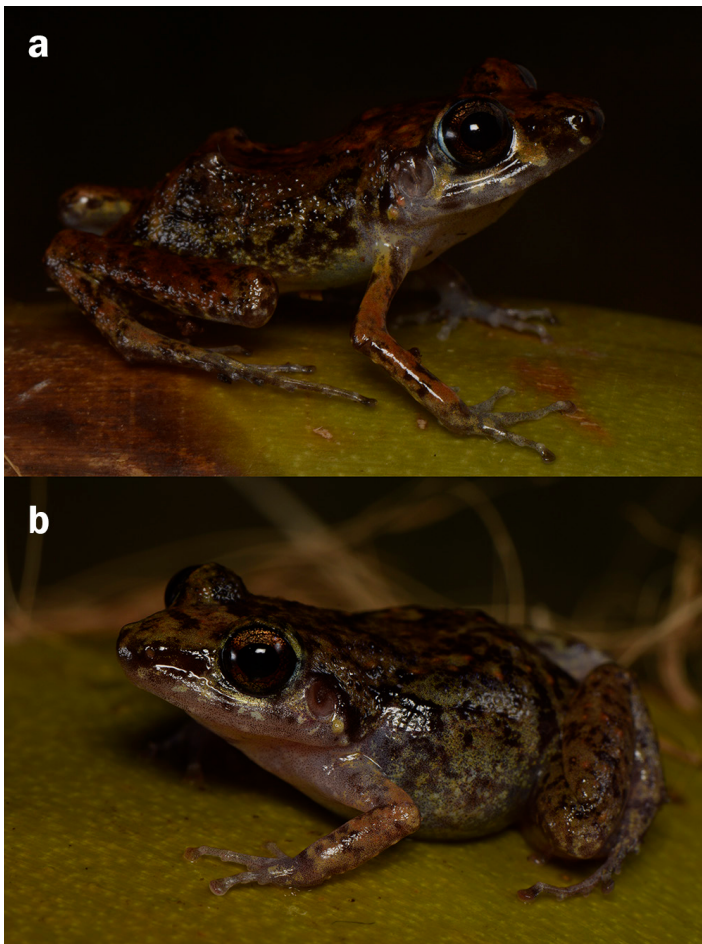


FIG. 2. *Eleutherodactylus planirostris* from San Andrés island, Colombia (uncollected specimens). Adult male (a); adult female (b). Photographs by L. E Vera-Pérez.

folds absent. Spicules, pustules, and warts absent. The anterior part of the belly smooth, and weakly areolated to areolated posteriorly. Discoidal and thoracic folds present. Forelimbs proportionately short ($HUL/SVL = 21.76\text{--}27.92\%$, $FOL/SVL = 20.28\text{--}28.72\%$), ulnar and antebrachial tubercles absent. Outer palmar tubercle cordiform, rounded, and well defined. Inner palmar tubercle oval and pointed at posterior border. Several small and rounded supernumerary tubercles. Fingers with well-defined subarticular tubercles and narrow lateral fringes. Relative size of fingers formula is $III > IV > II > I$. Discs of fingers slightly expanded and truncated, with circumferential groove and pads. Manual webbings absent. Hindlimbs proportionately short ($THL/SVL = 40.07\text{--}53.35\%$, $TL/SVL = 43.23\text{--}56.71\%$, $FL/SVL = 42.98\text{--}52.43\%$). Tarsal tubercles absent. Outer metatarsal tubercle medium-sized, with conical tip. Inner metatarsal tubercle oval and pronounced, with short, rounded lateral edges. Small and

round supernumerary tubercles are present on most of the plantar surface. Subarticular tubercles present and well defined and narrow lateral fringes. Relative size of toes formula is $IV > III > V > II > I$ or $IV > V \geq III > II > I$ (Fig. 4). Discs of toes slightly expanded and truncated, with circumferential groove and pads. Pedial webbings basal or absent.

Specimens of *Eleutherodactylus planirostris* from San Andrés exhibit a dark brown interorbital bar, lacking canthal stripes and facemask. The supratympanic stripes are dark brown and well defined. The upper lip has irregular dark brown blotches, separated by greenish spaces that extend from the tip of the snout to the canthus rostralis. The dorsal body pattern has a reddish-brown background with irregular dark brown blotches, which extend to the fore and hindlimbs and the dorsolateral portion. The dorsolateral stripes are light brown when present, or absent. The flank has irregular dark brown, reticulate blotches on an olive background. The belly is uniformly pale gray in the anterior portion, with slight yellow surfaces posteriorly. The weak advertisement calls of one to three short notes heard by us, are indistinguishable (to the human ear) from calls described by Schwartz (1974), Díaz and Cádiz (2007), and Alonso et al. (2007) for *E. planirostris*.

DISCUSSION

Natural history and implications of the new record

The record of *Eleutherodactylus planirostris* from San Andrés corresponds to the second frog and the eighth non-native species of herpetofauna documented from the Colombian Caribbean islands, as well as the first national record and the second invasive *Eleutherodactylus* reported from Colombian territory (Acosta-Galvis 2019). The greenhouse frog probably arrived on San Andrés through the trade of nursery plants, a typical way of human-assisted introduction for this and related species (Kraus et al. 1999; Heinicke et al. 2011; Leonhardt et al. 2019; Barrantes-Madrigal et al. 2019). Some studies based on molecular analyses have shown evidence that the presence of *E. planirostris* in Central America is related to Western Cuba and Florida populations (Crawford et al. 2011; McCranie and Valdés-Orellana 2014). Given the geographical proximity, it is possible that the populations on San Andrés are also closely related to them.

Díaz and Cádiz (2007) reported that *E. planirostris* is a very common and adaptable species, capable of tolerating all kinds of natural and synanthropic habitats in



FIG. 3. Egg mass of *Eleutherodactylus planirostris* found in a decayed coconut palm log. Thirteen eggs, CMUMAG:ANF:01195. Photograph by A. C. Montes-Correa.

its native distribution. Nevertheless, almost all records from Western Caribbean islands and Central America were found in synanthropic habitats, even in urban places far from natural vegetation (McCranie et al. 2008; Crawford et al. 2011; Barquero and Araya 2016; Gómez-Salazar and Cedeño-Vásquez 2017; García-Vinalay et al. 2020). Nevertheless, Antúnez-Fonseca et al. (2021) found that invasive populations of *E. planirostris* in Honduras can inhabit in natural disturbed habitats in the “spread” stage of invasion, according to the category D2 of the framework proposed by Blackburn et al. (2011) for biological invasions. Following this framework, the invasion of *E. planirostris* in San Andrés can be including in the “spread” stage, category D2, since there is evidence that its populations are abundant and reproduce in nature, without a doubt, in all the places where it lives throughout the island. However, it appears unable to penetrate the conserved forest remnants. Microhabitat use by individuals from San Andrés is very similar to data from Hawaii and Mexico, with observations in sites such as gardens and backyards

with abundant leaf-litter, grasses, flowerpots, and artificial water reservoirs (Olson and Beard 2012; Olson et al. 2012; Gómez-Salazar and Cedeño-Vásquez 2017).

The greenhouse frog populations have a high invasive potential due to their physiological tolerances to dry and warm conditions (Pough et al. 1979). Therefore, some introduced populations have shown high abundances (20 ind/km² in México; Gómez-Salar and Cedeño-Vásquez 2017) or densities (12,500 ind/ha⁻¹ in Hawaii; Olson and Beard 2012). This aspect, plus their voracious appetite (a consumption rate of 29,000 invertebrates per ha⁻¹ per night⁻¹ in Hawaii; Olson and Beard 2012) can generate severe impacts on the leaf-litter insect assemblages and soil nutrient cycles, as well as increasing competition with small native insectivores; as it has been evidenced for other introduced populations of *Eleutherodactylus* (Sin et al. 2008; Olson et al. 2012). Therefore, it is very probable that a proliferation of *E. planirostris* could affect the availability of food resources for *Sphaerodactylus argus andresensis* Dunn & Saxe, 1950, the smallest member of the Colombian



FIG. 4. Comparison of feet (upper) and hands (lower) between specimens of *Eleutherodactylus planirostris* from La Habana, Cuba (a, uncollected specimen) and San Andrés, Colombia (b, CBUMAG:ANF:01175). Photographs by J. D. Jiménez-Bolaño (San Andrés) and L. M. Díaz (Cuba).

Caribbean islands native herpetofauna, at least in synanthropic habitats. Future studies should be aimed to determine if: (1) the greenhouse frog has already colonized the other islands of the Colombian Caribbean, as well as (2) the ecological impacts of the introduction and establishment of this invasive species in San Andrés.

Morphological remarks

Eleutherodactylus planirostris is a polychromatic species. Our samples show two of the three known color morphs described by Díaz and Cádiz (2008), which consist of light dorsolateral stripes with dark margins or irregular blotches on all dorsal surfaces. Nevertheless, it is possible that all the morphs of the greenhouse frog are present on San Andrés, but it is necessary to

increase the sample size to determine this.

The general morphology of greenhouse frogs from San Andrés is consistent with descriptions by Barbour and Ramsden (1919), Grant (1949), and Schwartz (1960, 1974). However, we detected some variation in the relative size of toes for samples from San Andrés. Schwartz (1974) stated that relative size of foots in decreasing order was IV-III-V-II-I in native populations. This character was used as the starting point of the dichotomous key for New World direct developing frogs (Terrarana) of northern Central América by Köhler (2010), where this character state leads to *E. planirostris*. Therefore, that key was not useful to determine the specimens from San Andrés, because several of these have the toe V equal to longer than the III one. The condition of this character must be evaluated in other populations of the species to complement its diagnosis and description.

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