



# The most frog-diverse place in Middle America, with notes on the conservation status of eight threatened species of amphibians

<sup>1,2,\*</sup>José Andrés Salazar-Zúñiga, <sup>1,2,3</sup>Wagner Chaves-Acuña, <sup>2</sup>Gerardo Chaves, <sup>1</sup>Alejandro Acuña, <sup>1,2</sup>Juan Ignacio Abarca-Odio, <sup>1,4</sup>Javier Lobon-Rovira, <sup>1,2</sup>Edwin Gómez-Méndez, <sup>1,2</sup>Ana Cecilia Gutiérrez-Vannucchi, and <sup>2</sup>Federico Bolaños

<sup>1</sup>Veragua Foundation for Rainforest Research, Limón, COSTA RICA <sup>2</sup>Escuela de Biología, Universidad de Costa Rica, San Pedro, 11501-2060 San José, COSTA RICA <sup>3</sup>División Herpetología, Museo Argentino de Ciencias Naturales “Bernardino Rivadavia”-CONICET, C1405DJR, Buenos Aires, ARGENTINA <sup>4</sup>CIBIO Research Centre in Biodiversity and Genetic Resources, InBIO, Universidade do Porto, Campus Agrário de Vairão, Rua Padre Armando Quintas 7, 4485-661 Vairão, Vila do Conde, PORTUGAL

**Abstract.**—Regarding amphibians, Costa Rica exhibits the greatest species richness per unit area in Middle America, with a total of 215 species reported to date. However, this number is likely an underestimate due to the presence of many unexplored areas that are difficult to access. Between 2012 and 2017, a monitoring survey of amphibians was conducted in the Central Caribbean of Costa Rica, on the northern edge of the Matama mountains in the Talamanca mountain range, to study the distribution patterns and natural history of species across this region, particularly those considered as endangered by the International Union for Conservation of Nature. The results show the highest amphibian species richness among Middle America lowland evergreen forests, with a notable anuran representation of 64 species. The greatest diversity in the study area occurred in the mature forest on the basal belt. Of the 68 amphibian species found, seven (10%) are endemic to the Atlantic versant and eight (11.6%) are threatened. This survey includes the first record of *Gastrotheca cornuta* in Costa Rica since it was last reported 21 years ago. New populations of *Agalychnis lemur* (Critically Endangered) and *Duellmanohyla uranochroa* (Endangered) are reported, and *Ecnomiohyla veraguensis* (Endangered) is reported for the first time in Costa Rica. These findings show that this locality is a high priority conservation area for a large number of amphibian species, which are often threatened by habitat loss and fragmentation.

**Keywords.** Biodiversity, Costa Rica, Endangered, Limón province, patterns of distribution, Tropical Wet Forest

**Resumen.**—En anfibios, Costa Rica exhibe la mayor riqueza de especies por unidad de área en América Meridional con un total 215 especies documentadas a la fecha. Sin embargo, es probable que este número esté subestimado debido a la presencia de áreas inexploradas con difícil acceso. Entre 2012 y 2017, realizamos un monitoreo de anfibios en el Caribe Central de Costa Rica, en el borde norte de la Fila Matama en la Cordillera de Talamanca, para estudiar los patrones de distribución y la historia natural de las especies en esta región, particularmente aquellas consideradas en peligro por la Unión Internacional para la Conservación de la Naturaleza (UICN). Nuestros resultados muestran la mayor riqueza de especies de anfibios en los bosques perennes de tierras bajas de América Meridional, con una notable representación de anuros de 64 especies. La mayor diversidad en el área de estudio se encontró en el bosque maduro en el piso basal. Del total de especies, siete (10%) son endémicas de la vertiente Atlántico y ocho (11,6%) están amenazadas. Este es el primer registro de *Gastrotheca cornuta* en Costa Rica después de 21 años desde que se registró por última vez. Descubrimos nuevas poblaciones de *Agalychnis lemur* (en Peligro Crítico), *Duellmanohyla uranochroa* (en Peligro), y reportamos por primera vez *Ecnomiohyla veraguensis* (en Peligro) en Costa Rica. Nuestros resultados muestran que esta localidad es un área de alta prioridad para la conservación de una gran cantidad de especies de anfibios, a menudo amenazadas por la fragmentación y la pérdida de hábitat.

**Palabras clave.** Biodiversidad, Costa Rica, amenazado, provincia de Limón, patrones de distribución, Bosque Tropical Húmedo

**Citation:** Salazar-Zúñiga JA, Chaves-Acuña W, Chaves G, Acuña A, Abarca-Odio JI, Lobon-Rovira J, Gómez-Méndez E, Gutiérrez-Vannucchi AC, Bolaños F. 2019. The most frog-diverse place in Middle America, with notes on the conservation status of eight threatened species of amphibians. *Amphibian & Reptile Conservation* 13(2) [General Section]: 304–322 (e215).

**Copyright:** © 2019 Salazar-Zúñiga et al. This is an open access article distributed under the terms of the Creative Commons Attribution License [Attribution 4.0 International (CC BY 4.0)]: <https://creativecommons.org/licenses/by/4.0/>, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The official and authorized publication credit sources, which will be duly enforced, are as follows: official journal title *Amphibian & Reptile Conservation*; official journal website: [amphibian-reptile-conservation.org](http://amphibian-reptile-conservation.org).

**Received:** 21 March 2019; **Accepted:** 22 December 2019; **Published:** 30 December 2019

**Correspondence.** \*[jsalazar@veraguainforest.com](mailto:jsalazar@veraguainforest.com) (JASZ), [wchaves512@gmail.com](mailto:wchaves512@gmail.com) (WCA), [cachi13@gmail.com](mailto:cachi13@gmail.com) (GC), [alejandro21ucr@gmail.com](mailto:alejandro21ucr@gmail.com) (AA), [jiao24@gmail.com](mailto:jiao24@gmail.com) (JIAO), [j.lobon.rovira@hotmail.com](mailto:j.lobon.rovira@hotmail.com) (JLR), [gedgome@gmail.com](mailto:gedgome@gmail.com) (EGM), [anagv04@gmail.com](mailto:anagv04@gmail.com) (ACGV), [federico.bolanos@ucr.ac.cr](mailto:federico.bolanos@ucr.ac.cr) (FB)

## Introduction

Currently, more than 8,000 species of amphibians have been described worldwide, with the greatest diversity occurring in the Neotropics (Duellman 1999a; Frost 2019), where lower Central America stands out as a region with a substantial number of species (Campbell 1999; Duellman 2001; Savage 2002; Kubicki 2007). However, there has been an increase in the numbers of species designated as endangered throughout this region since the late 1980s due to habitat deforestation (Young et al. 2001; Stuart et al. 2004; Becker et al. 2007), climate change (Pounds et al. 1999; Hof et al. 2011), and infectious diseases (Lips et al. 2003; Pounds et al. 2006; Wake and Vredenburg 2008).

Tropical forests harbor a considerable number of amphibian species across distinct microhabitats that are often related to water-dependent sites such as ponds, temporary swamps, streams, tree holes, and bromeliad axils (Duellman 1970; Savage 2002; Lehtinen et al. 2004; Haddad and Prado 2005). However, many other amphibians exhibit reproductive modes that are totally independent from water bodies (Savage 2002). For instance, frogs of the genera *Gastrotheca* (Hemiphraetidae), *Eleutherodactylus* (Eleutherodactylidae), *Incilius* (formerly *Crepidophryne*: Bufonidae), *Craugastor*, *Pristimantis*, and *Strabomantis* (Craugastoridae) lay encapsulated eggs out of water, in which embryos undergo direct development and hatch out as small adults (Savage 2002; Gray and Bland 2016).

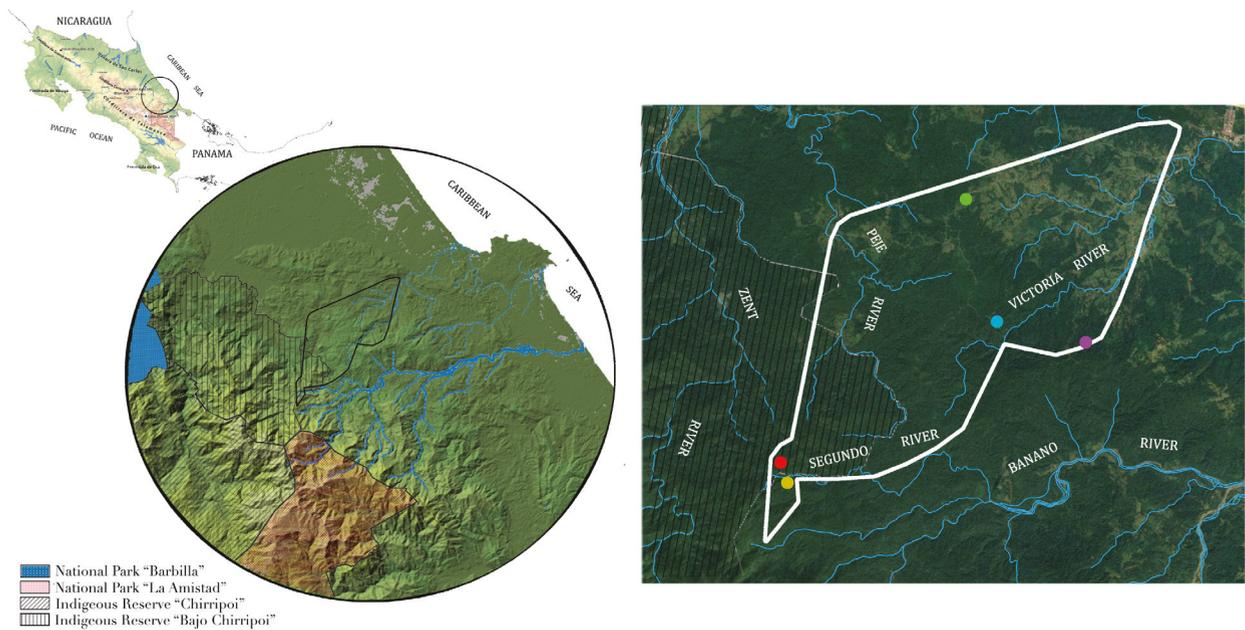
Costa Rica is known to possess considerable amphibian species richness per unit area (Savage 2002; Sasa et al. 2010; Bolaños et al. 2011). However, this great richness is likely to be underestimated due to the presence of undiscovered and undescribed species in areas that tend to be not easily accessible. To date, several previous works have reported countrywide amphibian checklists (Savage 2002; Bolaños et al. 2011; Leenders 2016). In particular, an increasing interest has focused on documenting species occurrence and the population status of threatened species in Costa Rica's montane ecosystems (Hayes et al. 1989; Abarca 2012; Acosta-Chaves et al. 2015; Rovito et al. 2015) and tropical forests of varying altitudinal gradients in the Pacific Slope throughout its South (McDiarmid and Savage 2005), Central (Laurencio and Malone 2009), and Northern regions (Sasa and Solorzano 1995). In contrast, the amphibian diversity of the Costa Rican Atlantic has been broadly documented almost exclusively in its Northern region (Donnelly and Guyer 1994; Guyer and Donnelly 2005; Whitfield et al. 2007). Only recently, Kubicki (2008) compiled the first list of species in premontane moist forests of the Costa Rican central-Caribbean. Although that inventory showed the relevant diversity of amphibians, little is known about the current population status and distribution of amphibian species across other areas of the mid-Caribbean.

Along this region, the Talamanca mountain range stands out as a predicted high priority conservation area for amphibians (García-Rodríguez et al. 2011). Considering that long-term monitoring can accurately assess population conditions (La Marca et al. 2005), species inventories are key to covering gaps in the distribution and natural history of endangered species in order to determine appropriate conservation strategies (Peloso 2010; Verdade et al. 2012). This study assessed the local richness and species distribution of amphibians in Veragua Rainforest Eco Research and Adventure Park and its surroundings on the northern edge of the Matama mountains in the Talamanca mountain range. Diversity analysis was conducted for different types of altitudinal belts, forests, and microhabitats found across the sampling area, and the population status of the threatened species in the study area are discussed.

## Materials and Methods

**Study area.** The study was conducted in the Central Caribbean of Costa Rica between Las Brisas de Veragua town (9°57'07"N, 83°12'11"E; 233 m asl) and Plátano peak (9°51'50"N, 83°14'10"E; 1,000 m asl) on the northern edge of the Matama mountains in the Talamanca mountain range, including Chimú peak (9°52'48"N, 83°14'13"E; 741 m asl) and Veragua Rainforest Park (VRP; 9°55'30"N, 83°11'28"E; 420 m asl; Fig. 1). This private reserve covers 3,200 ha of protected land ranging from 200–420 m asl, and it comprises mature forest, secondary vegetation at different stages of regeneration, open areas, and dirt roads. The study site lies adjacent to Victoria (9°55'21.73"N, 83°10'2.43"E; 410 m asl) on the Victoria river basin and the Matama mountains. This area is the closest point of the Talamanca mountain range to the Caribbean Sea and it forms part of the buffer zones of La Amistad International Park (an UNESCO World Heritage Site), the Banano river basin protected area, and the influence zones of the Zent, Peje, and Chirripó rivers, as well as the Bajo Chirripó indigenous reserve (SINAC 2018). Sampling was carried out along the elevation range 200–1,000 m asl, where two types of forest are located according to Holdridge (1967): Basal Tropical Wet Forest (200–600 m asl) and Premontane Tropical Wet Forest (601–1,000 m asl). Only these altitudinal belts are recorded and reported here, because they both represent the Tropical Wet Forest.

**Data collection.** Data were collected between January 2012 and December 2017. To record the species richness, samplings were standardized through diurnal and nocturnal visual and acoustic recognition searches (Crump and Scott 1994) into three transects: two in VRP, covering approximately 4 km each (Transects A and B), and one carried out along an 11 km trail between the reserve and Plátano peak (Transect C), including Chimú peak halfway along the route. On each of these



**Fig. 1.** Location of the study area (51 km<sup>2</sup>) in the Limón Province in the Central Caribbean area of Costa Rica. The colored points represent the main localities of the study area: yellow (Chimú Peak), red (Plátano Peak), blue (Veragua Rainforest Research and Adventure Park), green (Las Brisas), and purple (Victoria).

transects, surveyors walked side-by-side at a constant speed to record amphibian diversity on both sides of the trail (Seber 1986), covering up to 10 m from each side towards the forest. Transect A (300–420 m asl) was located along a dirt road inside the reserve in a secondary forest edge that included a 30 m wide natural pond and open areas. Transect B (200–400 m asl) covered forest trails and riparian environments within a mature forest. Transect C (400–1,000 m asl) comprised an old wood road (4 km) in a secondary forest and an indigenous trail (7 km) within a pristine environment that included natural ponds and riparian habitats along the trail.

From January 2012 to December 2012, Transect A or B was sampled weekly during the day (6:00–11:00 h) and at night (18:00–22:00 h), totaling 27 field days with four person hours (ph) per transect for a total search effort of 1,728 ph. Once a year, between 2012 and 2017, six expeditions at Transect C were conducted, totaling 13 field days of diurnal and nocturnal monitoring and a search effort of 1,560 ph. A leaf litter plot survey (Scott 1976) was used to sample ten plots (8 x 8 m) in Chimú peak (2014, 2017) and Plátano peak (2013, 2015) on an annual basis, for a total of 40 sampled plots.

The following information was recorded for the species detected during monitoring: 1. Holdridge altitudinal belts: basal (b) or premontane (p); 2. Type of forest: mature (M) or disturbed (D; includes secondary forest and open areas), and 3. Habitat association: riparian (R), forest (F), or swamp (S; including temporary or permanent ponds). If possible, one specimen per species was collected on each Holdridge life zone. The collected specimens were anesthetized and euthanized with lidocaine, fixed in a 10% buffered formalin solution, and later preserved in 70% ethanol solution. For all specimens, tissue samples

of muscle and liver were collected and fixed in 95% ethanol. Voucher specimens and tissue samples were deposited at the Museo de Zoología of the Universidad de Costa Rica (UCR). Some specimens were collected by third parties or other VRP researchers through occasional encounters in random field trips.

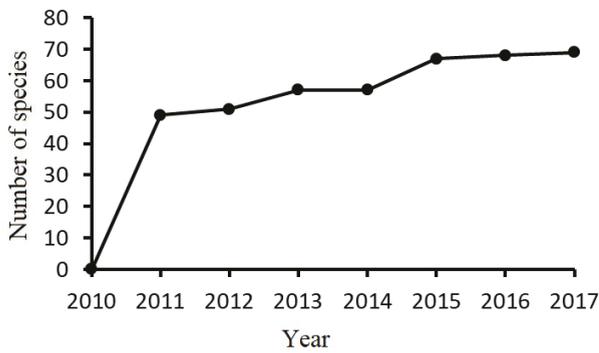
The species list includes the information obtained from this monitoring effort and UCR records of the Victoria locality, covering a study area of 51 km<sup>2</sup>, hereafter referred to as Veragua. Additional photographic material from collaborations with specialists in this area was evaluated. The taxonomic nomenclature follows Frost (2019), except for hylids in which Faivovich et al. (2018) was followed. The conservation status of each species was categorized according to the Red List of Threatened Species of the International Union for Conservation of Nature (IUCN 2019) and registered observations on the natural history of threatened species.

**Data analysis and permission.** The Jaccard index ( $I_j$ ) was used to determine the similarity in species composition between altitudinal belts, forest types, and habitat association. A species accumulation curve was performed to account for species richness. Sampling was conducted under research permit SINAC-ACLAC-PIME-VS-R-024-2016, granted by Sistema Nacional de Areas de Conservación (National System of Conservation Areas, SINAC).

## Results

### Overall Results

The surveys recorded a total of 68 species of amphibians, including 64 anurans distributed in 11

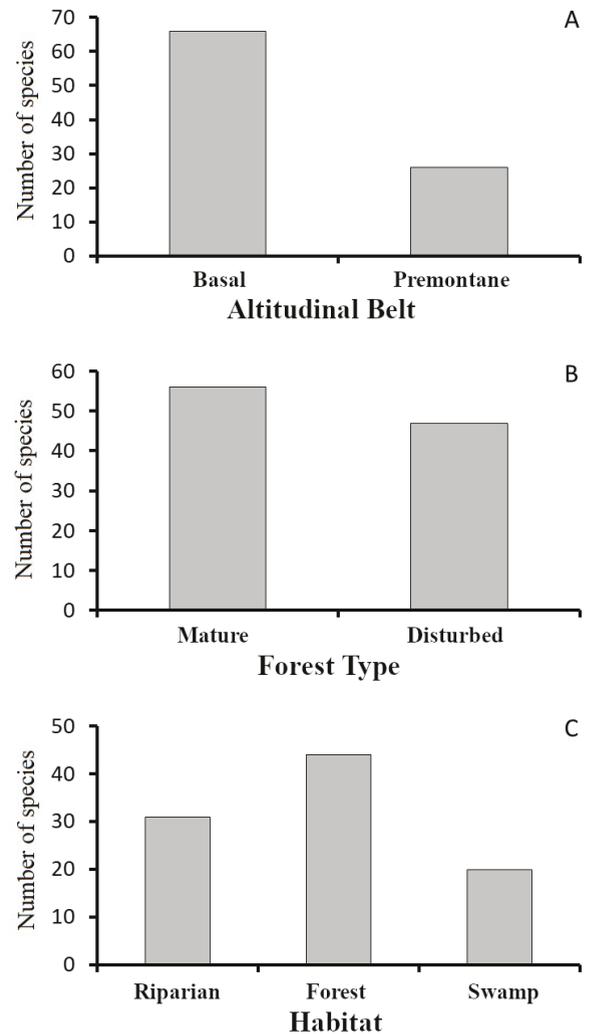


**Fig. 2.** Amphibian species accumulation curve for the 2010–2017 period in the study area.

families and 31 genera, three salamanders of the family Plethodontidae in two genera, and one caecilian in the family Caeciliidae (Table 1; Plates I–V). The most speciose families were Hylidae with 22 species (32.4%), followed by Craugastoridae with 15 species (21.7%) and Centrolenidae with 10 species (14.5%) [Table 1]. Six of the 68 species (8.7%) were endemic to the Atlantic slope of Costa Rica: *Bolitoglossa alvaradoi*, *Oedipina berlina*, *Craugastor persimilis*, *Diasporus amirae*, *Hyalinobatrachium diana*, and *Ecnomiohylla sukia*. The species accumulation curve reached an asymptotic phase at the end of the sampling period (Fig. 2).

Low species similarity was obtained between basal and premontane belts ( $I_j = 0.37$ ) and the majority of premontane species were found in the basal belt, except for *C. persimilis*, *D. amirae*, and *Pristimantis caryophyllaceus* (Table 1; Fig. 3a). Mature forests and disturbed areas were found to share slightly more than half of the species ( $I_j = 0.52$ ). A total of 19 species were only present in mature forests, and 14 species were detected only in disturbed areas (Table 1; Fig. 3b). The most diverse habitats were the forest (43 sp.) and riparian (31 sp.) environments, while 20 species were associated with swamps (Fig. 3c; Table 1). The results show that 44 species were only found in one type of habitat; out of these, the forest (19 sp.) was the most diverse habitat, followed by riparian environments (16 sp.) and swamps (9 sp.; Table 1). A medium-low similarity was found in the composition of species between the riparian and the forest (15 sp.;  $I_j = 0.25$ ), as well as between the swamps and the forest (11 sp.;  $I_j = 0.21$ ), although the data indicated only a minimal similarity when comparing rivers and swamps (2 sp.;  $I_j = 0.04$ ; Table 1). The only species that were found in all three habitats were *Agalychnis spurrelli* and *Rhinella horribilis*.

According to the IUCN conservation status, one species is categorized as Data Deficient (DD), 54 as Least Concern (LC), and eight in the various threatened categories. *Pristimantis altae* and *P. caryophyllaceus* are categorized as Near Threatened (NT); *Craugastor persimilis* as Vulnerable (VU); *Duellmanohyla uranochroa*, *Ecnomiohylla veraguensis*, *Gastrotheca cornuta*, and *Bolitoglossa alvaradoi* as Endangered



**Fig. 3.** Number of species registered according to the altitudinal belt (A), forest type (B), and habitat (C) in the study area.

(EN); and *Agalychnis lemur* as Critically Endangered (CR; Table 1). The species *Hyalinobatrachium diana*, *D. amirae*, *C. sylviae*, *E. sukia*, *Ecnomiohylla bailarina*, and *O. berlina* remain uncategorized (Table 1).

Regarding the uncategorized species populations, few populations of *H. diana* were observed in isolated streams within the basal mature forest. Populations with several individuals of *Diasporus amirae* were detected at the premontane belt. The species *C. sylviae* was found during 2011–2012 in only a few places within the forest. Generally, the adults were observed inside tree holes up to 3 m high. However, between 2012 and 2017, the species was more commonly observed reproducing throughout the year in VRP, near small artificial ponds (length 200 cm, width 150 cm, depth 50 cm) located within the forest. These ponds were created in 2012 by a project of the Veragua Foundation for the Rainforest Research “Veragua Foundation” (NGO) that aims to establish *in situ* breeding sites for the conservancy and study of the native amphibians. *Ecnomiohylla bailarina* and *E. sukia* were detected calling from the canopy in basal and premontane pristine forest. *Oedipina berlina*

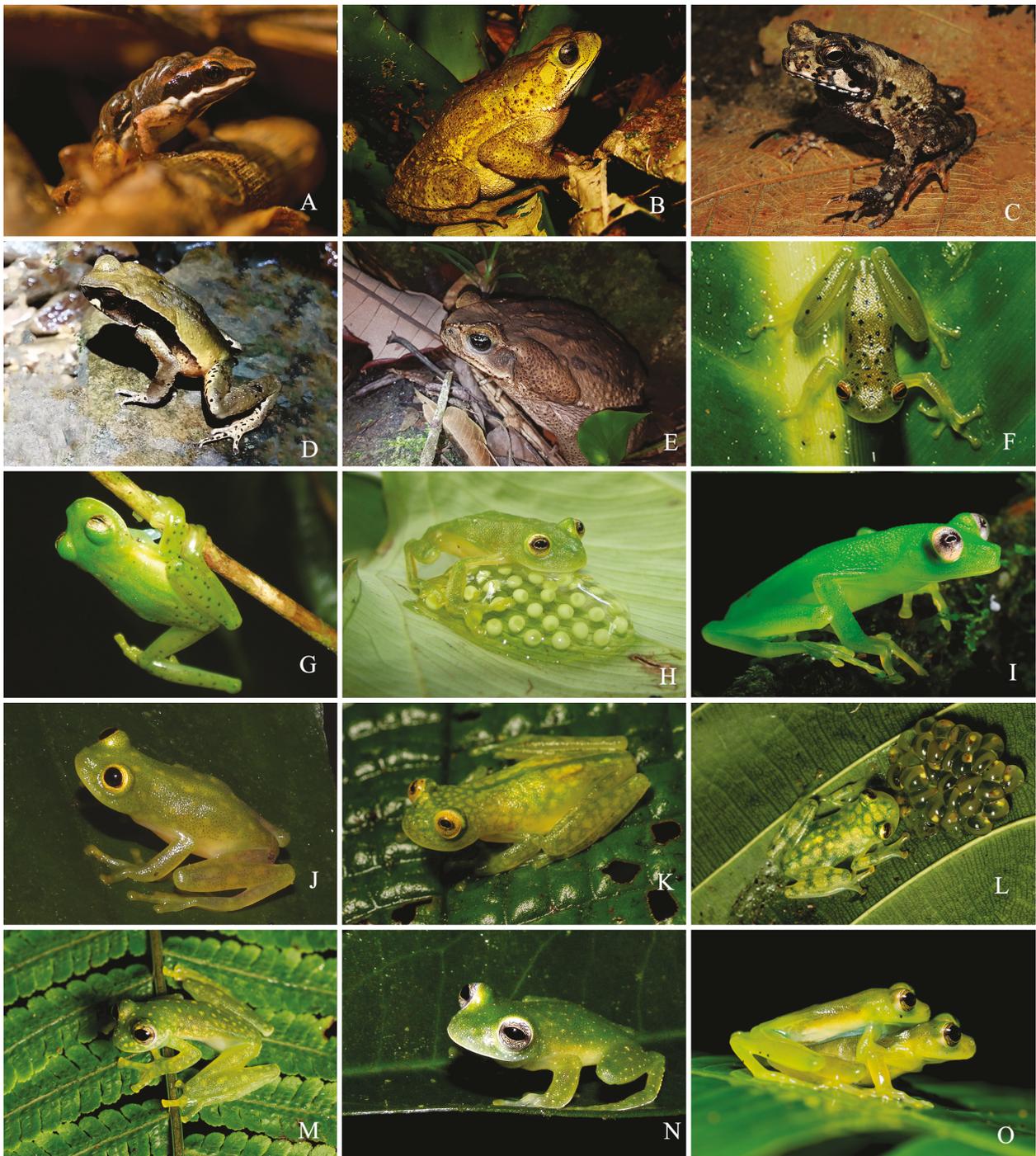
## Extreme frog diversity in Costa Rica

**Table 1.** Checklist of amphibians of the Veragua Rainforest Eco Research and Adventure Park and its surroundings, with information on the voucher ID (UCR), IUCN status, altitudinal belt (basal [b] / premontane [p]), forest type (mature [M] / disturbed [D]), and habitat association (forest [F] / swamp [S] / riparian [R]).

Taxa	UCR	IUCN status	Altitudinal Belts	Forest Types	Habitats
<b>Aromobatidae (1)</b>					
<i>Allobates talamancae</i> (Cope, 1875)	21593	LC	b p	M D	F S
<b>Bufonidae (4)</b>					
<i>Incilius coniferus</i> (Cope, 1862)	21164	LC	b	M D	F S
<i>Incilius melanochlorus</i> (Cope, 1877)	21983	LC	b p	M	R F
<i>Rhaebo haematiticus</i> Cope, 1862	21139	LC	b p	M D	R F
<i>Rhinella horribilis</i> (Wiegmann, 1833)	21148	LC	b	D	R F S
<b>Centrolenidae (10)</b>					
<i>Cochranella granulosa</i> (Taylor, 1949)	23183	LC	b	M D	R
<i>Espadarana prosoblepon</i> (Boettger, 1892)		LC	b	D	R
<i>Hyalinobatrachium chirripoi</i> (Taylor, 1958)	21431	LC	b p	M D	R
<i>Hyalinobatrachium diana</i> Kubicki, Salazar, and Puschendorf, 2015	22035		b	M	R
<i>Hyalinobatrachium fleischmanni</i> (Boettger, 1893)	23182	LC	b	M D	R
<i>Hyalinobatrachium talamancae</i> (Taylor, 1952)	21157	LC	b p	M	R
<i>Hyalinobatrachium valerioi</i> (Dunn, 1931)	21140	LC	b	M	R
<i>Sachatamia albomaculata</i> (Taylor, 1949)	21114	LC	b p	M D	R
<i>Teratohyla pulverata</i> (Peters, 1873)	21153	LC	b	M D	R
<i>Teratohyla spinosa</i> (Taylor, 1949)	21126	LC	b	M D	R
<b>Craugastoridae (15)</b>					
<i>Craugastor brandsfordi</i> (Cope, "1885," 1886)	21149	LC	b	D	F
<i>Craugastor crassidigitus</i> (Taylor, 1952)	21120	LC	b p	M D	R F
<i>Craugastor fitzingeri</i> (Schmidt, 1857)	21150	LC	b p	M D	F
<i>Craugastor gollmeri</i> (Peters, 1863)	22550	LC	b p	M	F
<i>Craugastor megacephalus</i> (Cope, 1875)		LC	b	M	F
<i>Craugastor mimus</i> (Taylor, 1955)	21414	LC	b	M D	F
<i>Craugastor noblei</i> (Barbour and Dunn, 1921)	21156	LC	b	M D	F
<i>Craugastor persimilis</i> (Barbour, 1926)	22529	VU	b	M	F
<i>Craugastor polyptychus</i> (Cope, 1886)	21121	LC	b p	M D	F
<i>Craugastor talamancae</i> (Dunn, 1931)		LC	b	D	R F
<i>Pristimantis altae</i> (Dunn, 1942)	21145	NT	b p	M D	R F
<i>Pristimantis caryophyllaceus</i> (Barbour, 1928)	21844	NT	p	M	F
<i>Pristimantis cerasinus</i> (Cope, 1875)	21127	LC	b p	M D	F
<i>Pristimantis cruentus</i> (Peters, 1873)	21170	LC	b p	M	R F
<i>Pristimantis ridens</i> (Cope, 1866)	21096	LC	b p	M D	R F
<b>Dendrobatidae (4)</b>					
<i>Dendrobates auratus</i> (Girard, 1855)	21128	LC	b	M D	F
<i>Oophaga pumilio</i> (Schmidt, 1857)	21106	LC	b p	M D	R F
<i>Phyllobates lugubris</i> (Schmidt, 1857)	21143	LC	b	M D	R F
<i>Silverstoneia flotator</i> (Dunn, 1931)	21986	LC	b p	M D	R F
<b>Eleutherodactylidae (2)</b>					
<i>Diasporus diastema</i> (Cope, 1875)	21415	LC	b p	M D	R F
<i>Diasporus amirae</i> Arias, Chaves, Salazar, Salazar-Zúñiga, and García-Rodríguez, 2019	22010		p	M	F

**Table 1 (continued).** Checklist of amphibians of the Veragua Rainforest Eco Research and Adventure Park and its surroundings, with information on the voucher ID (UCR), IUCN status, altitudinal belt (basal [b] / premontane [p]), forest type (mature [M] / disturbed [D]), and habitat association (forest [F] / swamp [S] / riparian [R]).

Taxa	UCR	IUCN status	Altitudinal Belts	Forest Types	Habitats
<b>Hemiphractidae (1)</b>					
<i>Gastrotheca cornuta</i> (Boulenger, 1898)	21017	EN	b p	M	R
<b>Hylidae (23)</b>					
<i>Agalychnis callidryas</i> (Cope, 1862)	21098	LC	b p	M D	F S
<i>Agalychnis lemur</i> (Boulenger, 1882)	21104	CR	b p	M D	S
<i>Agalychnis saltator</i> Taylor, 1955	21429	LC	b	M D	F S
<i>Agalychnis spurrelli</i> (Boulenger, 1913)	21119	LC	b	M D	R F S
<i>Boana rufitela</i> (Fouquette, 1961)		LC	b	M	S
<i>Cruziohyla sylviae</i> Gray, 2018	21422		b	M D	F S
<i>Dendropsophus ebraccatus</i> (Cope, 1886)	21103	LC	b	M D	S
<i>Dendropsophus phlebodes</i> (Stejneger, 1906)	21432	LC	b	D	S
<i>Duellmanohyla rufioculis</i> (Taylor, 1952)		LC	b p	M	R
<i>Duellmanohyla uranochroa</i> (Cope, 1875)	22002	EN	b p	M	R F
<i>Ecnomiohyla bailarina</i> Batista, Hertz, Mebert, Köhler, Lotzkat, Ponce, and Vesely, 2014	22287		b	M	F
<i>Ecnomiohyla sukia</i> Savage and Kubicki, 2010	22940		b p	M	F
<i>Ecnomiohyla veraguensis</i> Batista, Hertz, Mebert, Köhler, Lotzkat, Ponce, and Vesely, 2014	21941	EN	b p	M	F
<i>Hyloscirtus palmeri</i> (Boulenger, 1908)	21995	LC	b	M D	R
<i>Isthmohyla lancasteri</i> (Barbour, 1928)	21994	LC	b	M	R
<i>Scinax boulengeri</i> (Cope, 1887)		LC	b	D	S
<i>Scinax elaeochroa</i> (Cope, 1875)	21151	LC	b	D	F S
<i>Smilisca manisorum</i> (Taylor, 1954)		LC	b	D	S
<i>Smilisca phaeota</i> (Cope, 1862)	21113	LC	b	M D	S
<i>Smilisca puma</i> (Cope, 1885)		LC	b	D	S
<i>Smilisca sordida</i> (Peters, 1863)	21099	LC	b	M D	R
<i>Tlalocohyla loquax</i> (Gauge and Stuart, 1934)	21097	LC	b	M D	S
<b>Leptodactylidae (2)</b>					
<i>Leptodactylus melanonotus</i> (Hallowell, 1861)	21518	LC	b	D	F S
<i>Leptodactylus savagei</i> Heyer, 2005	20107	LC	b	M D	F S
<b>Microhylidae (1)</b>					
<i>Hypopachus pictiventris</i> (Cope, 1886)		LC	b	D	S F
<b>Ranidae (2)</b>					
<i>Lithobates vaillanti</i> (Brocchi, 1877)	21101	LC	b	D	R
<i>Lithobates warszewitschii</i> (Schmidt, 1857)	21102	LC	b	M D	R F
<b>Plethodontidae (3)</b>					
<i>Bolitoglossa alvaradoi</i> Taylor, 1952	22048	EN	b	M	F
<i>Bolitoglossa colonea</i> (Dunn, 1924)	21178	LC	b p	M D	F
<i>Oedipina berlini</i> Kubicki, 2016	22882		b	D	F
<b>Caeciliidae (1)</b>					
<i>Caecilia volcani</i> Taylor, 1969		DD	b	D	F



**Plate I.** Photos in life of amphibians recorded in the sampling area: (A) *Allobates talamancae*; (B) *Incilius coniferus*; (C) *I. melanochlorus*; (D) *Rhaebo haematiticus*; (E) *Rhinella horribilis*; (F) *Cochranella granulosa*; (G) *Espadarana prosoblepon*; (H) *Hyalinobatrachium chirripoi*; (I) *H. diana*; (J) *H. fleischmanni*; (K) *H. talamancae*; (L) *H. valerioi*; (M) *Sachatamia albomaculata*; (N) *Teratohyla pulverata*; and (O) *T. spinosa*. Photos by Víctor Acosta-Chaves (C, G, N); Javier Lobón-Rovira (A, F, L, M, O); José Andrés Salazar-Zúñiga (B, D, E, H, J, K); Andréi Solís (I).

was observed once in the secondary basal forest, as an individual was on the leaf litter on one of the trails of the Veragua Rainforest Park at night.

#### Observations on the Threatened Species

*Pristimantis altae* (NT; Plate II-K) was seen and heard in mature and secondary forests (Table 1). At the basal belt,

isolated males were recorded on riversides and inside the forest; nevertheless, at the premontane belt, groups of at least six calling males were registered, found very close to each other (2–3 m apart). At the premontane belt, *P. caryophyllaceus* (NT; Plate II-L) was commonly observed perched on leaves in the understory (100–150 cm high). On one occasion, a female was found in brooding position over a fully developed clutch with 26



**Plate II.** Photos in life of amphibians recorded in the sampling area: (A) *Craugastor brandsfordi*; (B) *C. crassidigitus*; (C) *C. fitzingeri*; (D) *C. gollmeri*; (E) *C. megacephalus*; (F) *C. mimus*; (G) *C. noblei*; (H) *C. persimilis*; (I) *C. polyptychus*; (J) *C. talamancae*; (K) *Pristimantis altae*; (L) *P. caryophyllaceus*; (M) *P. cerasinus*; (N) *P. cruentus*; (O) *P. ridens*. Photos by Víctor Acosta-Chaves (C, F); Javier Lobón-Rovira (B, K, O); José Andrés Salazar-Zúñiga (A, D, E, G–J, L–N).

eggs inside a partially rolled leaf at 1 m high. The female and her eggs were collected and placed in a plastic bag, and the next day all the eggs had hatched inside the bag. *Craugastor persimilis* (VU; Plate II-H) was observed several times during the plot survey, hidden in the leaf litter in the premontane belt.

*Duellmanohyla uranochroa* (EN; Plate IV-E) was detected in a few streams in pristine forest (Table 1). Males were observed calling from the streamside

vegetation. Also, a male chorus was heard inside the forest at a distance of at least 100 m from the nearest stream. Some of these individuals were located in between the aerial roots of a walking palm (*Socratea exorrhiza*). *Ecnomiohyla veraguensis* (EN; Plate IV-H) was observed once calling from the canopy in the basal mature forest. *Gastrotheca cornuta* (EN; Plate III-G) was uncommon in the survey samplings. Only two populations are known in the study area; one of them was last reported in 1996



**Plate III.** Photos in life of amphibians recorded in the sampling area (unless otherwise specified, all photographs refer to specimens detected in Veragua): (A) *Dendrobates auratus*; (B) *Oophaga pumilio*; (C) *Phyllobates lugubris*; (D) *Silverstoneia flotator*; (E) *Diasporus diastema*; (F) *Diasporus amirae*; (G) *Gastrotheca cornuta* (Veraguas, Panama); (H) *Agalychnis callidryas*; (I) *A. lemur*; (J) *A. saltator*; (K) *A. spurrelli*; (L) *Boana rufitela*. Photos by Abel Batista (G); Javier Lobón-Rovira (A–C, E, H, I, K, L); José Andrés Salazar-Zúñiga (D, F, J).

at 200 m asl in the Victoria river basin (Solorzano et al. 1998), and the subsequent record was published 16 years later, in the streamside vegetation in a deep canyon of the Zent River at 550 m asl (Salazar 2015).

Three populations of the Critically Endangered *Agalychnis lemur* (Plate III-I) were observed throughout Veragua. One of the populations was located in a pond (width 35 m) in a mature premontane forest, where many males were observed calling from the vegetation at 50–150 cm high. The other two populations were found in secondary forest at the basal belt, including a population that is on the border of the VRP (Table 1). Outside the reserve, this species was observed in small ponds and flooding banks next to a wood extraction road. Thus, given this immediate threat, small artificial ponds (length 200 cm, width 150 cm, depth 50 cm) were created by the Veragua Foundation during 2015

to protect this population. As of 2016, it was easier to observe individuals throughout the year during high-humidity nights near these reproductive sites.

## Discussion

With 215 species, Costa Rica is the 19<sup>th</sup> richest country in the world for amphibians, and exhibits the highest richness per unit area in Middle America (Kubicki 2008; Frost 2019). In this region, amphibian species density seems to be greater towards the South, specifically in Costa Rica and Panama (Campbell 1999). The results presented here show that Veragua exhibits the highest known species richness among Middle American lowland evergreen forests. With a notable anuran representation of 64 species in 51 km<sup>2</sup> surveyed (Table 1; Plates I–V), these



**Plate IV.** Photos in life of amphibians recorded in the sampling area (unless otherwise specified, all photographs refer to specimens detected in Veragua): (A) *Cruziohyla sylviae*; (B) *Dendropsophus ebraccatus*; (C) *D. phlebodes*; (D) *Duellmanohyla ruftoculis*; (E) *D. uranochroa*; (F) *Ecnomiophyla bailarina* (Darién, Panamá); (G) *E. sukia*; (H) *E. veraguensis* (Veraguas, Panamá); (I) *Hyloscirtus palmeri*; (J) *Isthmohyla lancasteri*; (K) *Scinax boulengeri*; (L) *S. elaeochroa*; (M) *Smilisca manisorum*; (N) *S. phaeota*; (O) *S. puma*; (P) *S. sordida*; (Q) *Talocohyla loquax*. Photos by Víctor Acosta-Chaves (M); Abel Batista (F); Edwin Gómez-Méndez (O); Daniel Hernández (C); Andreas Hertz (H); Javier Lobón-Rovira (A, B, J, N); José Andrés Salazar-Zúñiga (D, E, G, I, K, L, P, Q).



**Plate V.** Photos in life of amphibians recorded in the sampling area: (A) *Leptodactylus melanonotus*; (B) *L. savagei*; (C) *Hypopachus pictiventris*; (D) *Lithobates vaillanti*; (E) *L. warszewitschii*; (F) *Bolitoglossa alvaradoi*; (G) *B. colonnea*; (H) *Oedipina berlini*; (I) *Caecilia volceni*. Photos by Víctor Acosta-Chaves (C, D, F); Esmeralda Arévalo (I); Javier Lobón-Rovira (E); José Andrés Salazar-Zúñiga (A, B, G, H).

surveys reveal one of the highest numbers of amphibian species reported per unit area in the Neotropics (Savage 2002; Boza-Oviedo et al. 2012; Barrio-Amorós et al. 2011; Hertz et al. 2012; Arias and Bolaños 2014; Ferreira et al. 2017).

In comparison with the most important diversity hot spots from South America, the richest region of amphibian species worldwide (Ron et al. 2018; Frost 2019), Veragua is also one of the most diverse localities in the Neotropics with 68 species. Only certain sites across the Amazon lowlands exhibit a greater richness of amphibians than these Veragua sites (Barrio-Amorós et al. 2011; Ferreira et al. 2017). For example, amphibian richness in Brazil ranged from 18 species (Alter do Chão, Pará) to as many as 78 species along a small section of the Juruá river (Zimmermann and Rodrigues 1990; Lima 2008; Queiroz et al. 2011; Pereira-Júnior et al. 2013; Araújo and Costa-Campos 2014; Alves-Binício and Dias-Lima 2017; Ferreira et al. 2017; Lima et al. 2017), with the extreme exception of 109 amphibian species in the middle of the Xingu River (Vaz-Silvia et al. 2015; Ferreira et al. 2017). In Peru, the most diverse sites are in Bajo Río Lullapichis (74 sp.; Schluter et al. 2004), Parque Nacional Manu (68 sp.; Morales and McDiarmid 1996), and Cuzco Amazónico (64 sp.; Duellman 2005; Barrio-Amorós et al. 2011). In Colombia, the highest diversity was found in Leticia 97 species (Lynch 2005),

Amphib. Reptile Conserv.

and the two most important inventories reported in Ecuador are from the village of Santa Cecilia (87 sp.; Duellman 1978) and Parque Nacional Yasuní (135 sp.), currently the most diverse amphibian site in the world (Ron et al. 2018).

In Costa Rica, the amphibian richness is concentrated in the southern lowlands of the country and in the northeastern Atlantic versant (Campbell 1999; McDiarmid and Savage 2005; Santos-Barrera et al. 2008). Compared to the three other major inventories in these areas, Veragua is more species-rich than either the South Pacific locality of Rincón (47 sp., Anura [42]/Caudata [4]/Gymnophiona [1]; McDiarmid and Savage 2005), the Atlantic versant sites of La Selva Biological Station (52 sp., 47/3/1; Guyer and Donnelly 2005), or Guayacán (66 sp., 58/6/2; Kubicki 2008). Other important inventories were reported in a transitional wet-dry forest in the locality of Carara (39 sp.; Laurencio and Malone 2009), and among the richest sites in dry forests is Finca Taboba, at the northern edge of the country (21 sp.; Campbell 1999).

The low diversity of salamanders found in Veragua could be due to fact that the sampling area was below 1,100 m asl, and that only one monitoring was conducted per year in the premontane belt. It is also possible that the sampling method was not inclusive enough to cover a broader diversity in the basal belt. The number of frog and

salamander species distributed along specific elevations in Middle America follows a pattern previously noted in Guatemala and Belize, i.e., a moderate number of species in the lowlands that progressively increases as it reaches moderate or intermediate elevations, and then declines precipitously at higher elevations (Campbell and Vannini 1989; Wells 2007). Salamanders partly show this pattern as they exhibit a more dramatic increase in species in the highlands (Campbell 1999; Wells 2007). We presume that some other species, such as *Bolitoglossa striatula*, *Nototriton matama*, *Oedipina carablanca*, and *Oedipina gracilis*, which occur in the Atlantic Versant at a similar altitudinal belt and close to the Talamanca mountain range (Savage 2002; Kubicki 2008; Leenders 2016), could also occur in Veragua. Among caecilians, only *Caecilia volceni* was found. The apparent low diversity in this group is probably caused by its fossorial habits (Peloso 2010; Ferreira et al. 2017) which undermine effective sampling. We think that at least one common caecilian species in the Atlantic Versant (*Gymnophis multiplicata*) could be present in Veragua (Leenders 2016).

In this study, the basal belt was found to be more diverse than the premontane (Fig. 3; Table 1). This is a generalized pattern of distribution among anurans (Savage 2002) and should account for the vast representation of frogs and toads in this study, which represent 94% of the total amphibian species. The latter species distribution is similar to that of the wet slopes of the Andes, the region with the highest diversity of anuran species in the world (Duellman 1999b; Wells 2007). The higher number of anuran species in old mature forests compared with disturbed areas might be explained by the presence of more microhabitats in pristine environments (Table 1; Savage 2002; Acosta-Chaves et al. 2015). Nevertheless, one of the main factors shown to influence high local and regional diversity is the variety of habitats with numerous vegetation types, ranging from forests to open grasslands, that occur side-by-side in the landscape, each of them harboring a different array of species (Colli et al. 2002; Nogueira et al. 2009; Lopes-Santos et al. 2014).

The greatest species diversity and the highest level of endemism for amphibians in Middle America occur along the windward mesic slopes of major mountain ranges between elevations of 800 and 2,800 m asl, which in Costa Rica include the Guanacaste, Tilarán, and Talamanca mountain ranges (Campbell 1999). The Talamanca mountain range is recognized as a site of speciation and a dispersion center for several species with a high degree of endemism (Arias and Bolaños 2014). Among amphibians and reptiles, 27% of the species in Costa Rica are endemic to this region (Campbell 1999; Savage 2002; Chaves et al. 2009; Streicher et al. 2009; Boza-Oviedo et al. 2012; Arias and Bolaños 2014). In this study, 8.7% of the amphibians are endemic to the Atlantic Versant of Costa Rica (Campbell 1999; Leenders 2016; Frost 2019), including species of the genera *Duellmanohyla* and *Isthmohyla*, which are endemic to

Middle America (Faivovich et al. 2018).

A high number of species was found along the forest and the riparian habitats (Fig. 3; Table 1). This association with a type of forest might be due to the great variety of microhabitats found throughout these environments that result from irregular topography (Wells 2007; Kubicki 2008). Leaf litter is an important habitat for anurans, especially among species with terrestrial reproduction (although it is not restricted to them; Wells 2007). The high moisture levels found in the forest floor allow terrestrial species to forage and call during either the day or night (Wells 2007). The species richness of leaf litter frogs and toads is positively correlated with the number of wet months and the litter mass depth (Wells 2007; Whitfield et al. 2007).

The distribution along the riparian habitats was found to be non-uniform, as it could rely on vegetation coverage and the physical characteristics of the environment. The high number of amphibian species found along riparian habitats in this study could be due to the numerous springs, streams, and torrents found throughout the sampling area (Fig. 1), which generate several microhabitats along this environment (McDiarmid and Savage 2005; Kubicki 2007; SINAC 2018). Previous studies found a similar distribution pattern in Guayacán, where 35% of the species are associated with lotic environments (Kubicki 2008), while glass frogs represent more than 16% of the amphibian diversity in La Selva (Guyer and Donnelly 2005) and Rincón (McDiarmid and Savage 2005). In the mountainous regions of Middle America, the permanent or temporary ponds required for amphibian breeding are often scarce (Wells 2007). This pattern is also seen at Veragua and Guayacán, where the highly irregular topography of these localities causes permanent ponds to be a much more limited resource for reproduction (Kubicki 2008). Nevertheless, pond-breeders account for a notable representation of anuran species in Veragua (32, 4%) and Guayacán (30%; Kubicki 2008).

The species accumulation curve reached an asymptote, meaning that the sampling effort to detect species produced a number near the maximum expected value (Fig. 2). Nevertheless, there may be some cryptic species groups with high variation, and this fact may obscure the estimates given here, as different species could be hidden under a single name (Funk et al. 2012; Alves-Binicio and Dias-Lima 2017). However, the clarification of such unknown diversity requires further integrative taxonomic studies. Likewise, we suggest a larger survey effort in the premontane belt, since the difficult access to sampling areas did not allow for a continuous sampling.

### Comments on Threatened Species

This study registered *P. altae* (NT), which has been previously reported in very few places on the Atlantic Slope of Costa Rica and northwestern Panama (Leenders 2016). Overall, there is only limited information about

its natural history, population trends, and conservation needs (Leenders 2016). Historically, *P. altae* has been associated with undisturbed areas (Savage 2002; Pounds et al. 2008a). Even though this species was observed in mature forests, it was also commonly detected close to streams within secondary forests. According to Savage (2002), this species is mute; however, during high humidity dark nights it is common to hear the species emitting a short two note call “clock-clock,” similar to the sound that two glass marbles emit when they hit each other twice very rapidly. In basal secondary forests, isolated males were heard calling in the forest. However, on the premontane belt, this species is more abundant, and several males were heard calling at a close distance from each other. Unfortunately, the calls are emitted sporadically, and have not yet been recorded.

In this study, *P. caryophyllaceus* (NT) was one of the most common frogs in the mature premontane belt. During the mid-1980s, when many populations in Costa Rica declined (Leenders 2016), *P. caryophyllaceus* disappeared from most lowlands; however, it persisted at higher elevations (Leenders 2016). This pattern is rare among Neotropical anurans, considering that more pronounced declines generally occur at mid- and high elevations; in Panama, populations declined dramatically in some highlands, but in Costa Rica they seem to be recovering in areas above 800 m asl (Savage 2002; Pounds et al. 2008b; Leenders 2016). A female was found inside a rolled leaf at 100 cm above the forest floor attending a mass of 29 eggs. This same behavior was previously reported in Panamanian populations by Myers (1969). Recent research showed that *Craugastor persimilis* (VU) is susceptible to habitat fragmentation and it is often absent in open pasture lands and pineapple plantations (Bolaños et al. 2008). This observation is consistent with the observations reported here, as this species was only observed in the mature premontane forest.

*Duellmanohyla uranochroa* (EN) was a historically common species across humid lowland and mountain forests (Savage 2002). However, it has declined precipitously since the late 1980s. By 2002, *D. uranochroa* had experienced a significant decline across several populations in Costa Rica (Duellman 2001; Savage 2002; Leenders 2016; IUCN 2019). However, since 2007 some populations have reappeared in Monteverde, the Matama mountains, and Tuis de Turrialba (NatureServe and IUCN 2013), as well as in western Panama (Hertz et al. 2012). In this monitoring effort, populations were observed at the premontane and basal belt of the mature forest, sometimes close to riparian environments. Generally, males were found on the forest floor or on walking palm roots, and up to 2 m high. Similar behaviors have been reported in other populations of this species (Duellman 2001; Savage 2002; NatureServe and IUCN 2013).

Before this report, *Ecnomiohyla veraguensis* was only known from two small Panamanian populations in Santa Fé National Park, where it is highly threatened by

ongoing habitat modification due to forest clearance for agriculture and open pit mining (IUCN SSC Amphibian Specialist Group 2019). *Ecnomiohyla veraguensis* is differentiated here from *E. miliaria*, another congener from the Caribbean foothills, based on the presence of scalloped fleshy fringes and the absence of heel tubercles in the former (Batista et al. 2014); from *E. bailarina*, considering that *E. veraguensis* has a finely tuberculate dorsum (strongly tuberculate in *E. bailarina*) with scattered minute keratin tipped tubercles on the posterior part of the body and 6–8 widely spaced, keratinized black spines bordering the outer side of the thumb (two clusters of numerous, small nuptial spines in *E. bailarina*; Batista et al. 2014). The most similar species to *E. veraguensis* is *E. sukia*; however, the latter lacks nuptial spines in adult males (Batista et al. 2014).

*Gastrotheca cornuta* (EN) is considered a rare species in Colombia and Costa Rica, while it has declined in Ecuador and Panama (Coloma et al. 2008; AmphibiaWeb 2009). In Costa Rica, this species is known from only three localities in the Limón Province (Coloma et al. 2008). The first specimen was collected during 1984 in the northwest of Nimaso peak in the Talamanca Mountain range at 700 m asl (Solorzano et al. 1998; Savage 2002). The other two localities were reported in Veragua, also at basal mature forests (Solorzano et al. 1998; Salazar 2015).

*Bolitoglossa alvaradoi* (EN) was only observed once in the mature forest. This endemic species has only been reported in undisturbed areas and it is considered endangered because its extent of occurrence is less than 5,000 km<sup>2</sup> (Bolaños et al. 2008). This salamander is a rare species, mostly due to its secretive arboreal habitats (Bolaños et al. 2008). In the current survey, this species was found during the day near a small stream on a leaf at 100 cm. Some other studies reported individuals inside bromeliads and leaf axils during the day (Wake 1987; Savage 2002).

*Agalychnis lemur* (CR) occurs in Costa Rica, Panama, and marginally in Colombia (Solís et al. 2008). It inhabits basal and premontane humid forests and has been historically associated with pristine areas (Duellman 2001; Savage 2002). This species has always been fairly uncommon throughout its range; however, it was listed as Critically Endangered because of ongoing drastic population declines, estimated to be more than 80% over a ten-year period (Solís et al. 2008). This survey found three separate natural breeding populations in the study area. One of these populations was already reported in Costa Rica and was considered the only remnant wild breeding population (Solís et al. 2008). Another small population was reported in Guayacán (Kubicki 2008; Solís et al. 2008). All other previously known Costa Rican populations of this species have disappeared, including those in Monteverde, San Ramón, Braulio Carrillo, and Tapanti (Solís et al. 2008).

The main threats reported for *A. lemur* are habitat

destruction and chytridiomycosis (Solís et al. 2008). In one of the reported populations in this study, Whitfield et al. (2017) found a low infection prevalence (<10%,  $n = 20$ ) of *Batrachochytrium dendrobatidis* (*Bd*) and a low infection intensity among infected individuals. Some studies demonstrated that highly *Bd*-susceptible amphibians persist in environments hostile to *Bd*, even when *Bd* is still present (Puschendorf et al. 2011). The samplings reported here never registered a sick animal. Nonetheless, in some places where it was common to see the species during the sampling surveys, *A. lemur* had disappeared after the intensification of wood extraction during 2013. *Agalychnis lemur* appears to be highly susceptible to habitat loss, and the lack of natural reproductive sites in the forest promotes the use of the flooding banks or small ponds at the forest edge (JASZ, pers. obs.), a condition that we consider makes this species extremely vulnerable to habitat fragmentation.

This study shows that the threatened species reported here are associated with mature forest. These species may be sensitive to changes in their environment and might therefore exhibit a low tolerance to human impact (Dixo and Martins 2008; Lopes-Santos et al. 2018). The main biodiversity threats observed while conducting this study were: 1. Habitat destruction (legal or illegal) due to population growth, pastures, and extraction labors for wood and stone; 2. Monocultures of extensive plantations (e.g., by banana and pineapple corporations in the nearby lowlands), that also create substantial soil erosion and use numerous agrochemicals to maintain the crops, producing substantial amounts of pollution residues (Castillo et al. 1997; Castillo and Ruepert 2001; Sasa et al. 2010); 3. Illegal wildlife extraction; 4. Little control by the responsible authorities; and 5. Low levels of environmental education.

## Conclusions

This survey shows that Veragua is a high priority conservation area with 11.7% of its amphibian diversity under the IUCN threatened categories, out of which five species are cataloged as Endangered or Critically Endangered (Table 1; IUCN 2019). In addition, this study reports *E. veraguensis* in Costa Rica for the first time and represents the only locality known for *E. bailarina* (Kubicki and Salazar 2015). The diversity analysis reveals one of the most important amphibian hot spots in the Neotropics, with evidence of recent sightings of several species after concerning declines (like those of *Duellmanohyla uranochroa* and *Agalychnis lemur*), and contrasts with the decimated diversity in several other important locations in Costa Rica (e.g., La Selva, Rincón de Osa, Cerro Chompipe, Monteverde, Cerro de la Muerte, Tapanti, Volcán Cacao, Palmar Norte, and Las Tablas) that have declined or disappeared since the late 1980s (Whitfield et al. 2007; Sasa et al. 2010; Ryan et al. 2015). Based on these findings, we suggest a long-term

monitoring of the biodiversity in order to have control over population fluctuations, and we highly recommend natural history and behavioral studies to improve conservation actions across this biodiversity hot spot. According to the international conservation agreements, as well as Costa Rica's laws and executive decrees, the information provided in this article should help to protect the area from invasive activities that may negatively affect the biodiversity or major river basins (Sasa et al. 2010).

**Acknowledgements.**—This research was possible thanks to the invaluable help of the following group of researchers and field assistants: José Brenes-Andrade, Andrés Rojas-Valle, Erick Arias, Diana Salazar, Iria Chacón, Víctor Acosta-Chaves, Adrián García-Rodríguez, Marcelo Elizondo, Rolando Ramírez, Julissa Gutiérrez-Figueroa, Irene Ossenbach, Alejandro Quesada-Murillo, Melissa Díaz-Morales, and Diego Salas. For photographic material, we are thankful for the collaboration of Víctor Acosta-Chaves, Esmeralda Arévalo-Huezo, Abel Batista, Daniel Hernandez, Andreas Hertz, and Andréi Solís. We also appreciate the help of Tim Bray and Cesar Barrios-Amorós as external reviewers, and Steve McCormack and Cindy Chaves as English reviewers. It is important to highlight the participation of Luis Angel Mejia Gonzales (Pecas), Stanley Salazar, and Julian Solano Salazar for their great efforts in searching for and finding the species *Gastrotheca cornuta* and the three species of *Ecnomiohyla*; to Johnny Hernandez and the sisters Mariana and Isabella Jiménez for finding the species *Oedipina berlina*; and to Esmeralda Arévalo-Huezo and the zoology class (2018) of the Universidad Latina (Costa Rica) for finding the only caeciliid in the survey (*C. volceni*). We are very grateful for the participation of the local people of the communities of Las Brisas, El Peje, and the Cabecar Ethnic Group, especially to the indigenous leader Ruperto López Camacho, who shared his knowledge and guided us into the pristine forest. We appreciate the logistic support provided by the School of Biology and the Museum of Zoology of the University of Costa Rica, as well as the great help from the employees of Veragua Rainforest Research and Adventure Park to conduct this project. Finally, we thank The Veragua Foundation for the Rainforest Research and its president, José Martí Jiménez-Figueroa, for financing, believing, and supporting this important research for the conservancy.

## Literature Cited

- Abarca JG. 2012. Cambios en la estructura de la comunidad de anuros (Amphibia: Anura) en el Cerro Chompipe. *Cuadernos de Investigación UNED* 4: 9–15.
- Acosta-Chaves VJ, Chaves G, Abarca JG, García-Rodríguez A, Bolaños F. 2015. A checklist of the

- amphibians and reptiles of Río Macho Biological Station, Provincia de Cartago, Costa Rica. *Check List* 11: 1–10.
- Alves-Binício R, Dias-Lima J. 2017. Anurans of Amapá National Forest, Eastern Amazonia, Brazil. *Herpetology Notes* 10: 627–633.
- AmphibiaWeb. 2009. *Gastrotheca cornuta*. University of California, Berkeley, California, USA. Available: <http://amphibiaweb.org/species/1371> [Accessed: 1 November 2018].
- Araújo AS, Costa-Campos CE. 2014. Anurans of the Reserva Biológica do Parazinho, Municipality of Macapá, state of Amapá, eastern Amazon. *Check List* 10: 1,414–1,419.
- Arias E, Bolaños F. 2014. A checklist of the amphibians and reptiles of San Isidro de Dota, Reserva Forestal Los Santos, Costa Rica. *Check List* 10: 870–877.
- Barrio-Amorós CL, Brewer-Carías C, Fuentes O. 2011. Aproximación preliminar a la herpetocenosis de un bosque pluvial en la sección occidental de la Sierra de Lema, Guayana Venezolana. *Revista de Ecología Latinoamericana* 16: 1–46.
- Batista A, Herts A, Mebert K, Köhler G, Lotzkat S, Ponce M, Vesely M. 2014. Two new fringe-limbed frogs of the genus *Ecnomiohyla* (Anura: Hylidae) from Panama. *Zootaxa* 3826(3): 449–474.
- Becker CG, Fonseca CR, Haddad CFB, Batista RF, Prado PI. 2007. Habitat split and the global decline of amphibians. *Science* 318: 1,775–1,777.
- Bolaños F, Savage JM, Wake DB. 2008. *Bolitoglossa alvaradoi*. *The IUCN Red List of Threatened Species* 2008: e.T59138A11888362.
- Bolaños F, Savage JM, Chaves G. 2011. *Anfibios y Reptiles de Costa Rica*. Listas Zoológicas Actualizadas Universidad de Costa Rica, Museo de Zoología UCR, San Pedro, Costa Rica. Available: <http://museo.biologia.ucr.ac.cr/Listas/LZAPublicaciones.htm> [Accessed: 1 August 2018].
- Boza-Oviedo E, Rovito SM, Chaves G, García-Rodríguez A, Artavia LG, Bolaños F, Wake DB. 2012. Salamanders from the eastern Cordillera de Talamanca, Costa Rica, with descriptions of five new species (Plethodontidae: *Bolitoglossa*, *Nototriton*, and *Oedipina*) and natural history notes from recent expeditions. *Zootaxa* 3309: 36–61.
- Campbell JA. 1999. Distribution patterns of amphibians in Middle America. Pp. 111–210 In: *Patterns of Distribution of Amphibians. A Global Perspective*. Editor, Duellman WE. Johns Hopkins University Press, Baltimore, Maryland, USA. 648 p.
- Campbell JA, Vannini JP. 1989. Distribution of amphibians and reptiles in Guatemala and Belize. *Proceedings of the Western Foundation of Vertebrate Zoology* 4: 1–21.
- Castillo LE, Ruepert C. 2001. *Estudio preliminar de la calidad del agua superficial en la zona de Volcán de Puntarenas, Buenos Aires de Puntarenas*. Instituto Regional de Sustancias Tóxicas, Universidad Nacional, Heredia, Costa Rica. Available: [https://www.researchgate.net/publication/326929351\\_ESTUDIO\\_PRELIMINAR\\_DE\\_LA\\_CALIDAD\\_DEL\\_AGUA\\_SUPERFICIAL\\_EN\\_LA\\_ZONA\\_DE\\_VOLCAN\\_BUENOS\\_AIRES\\_DE\\_PUNTARENAS](https://www.researchgate.net/publication/326929351_ESTUDIO_PRELIMINAR_DE_LA_CALIDAD_DEL_AGUA_SUPERFICIAL_EN_LA_ZONA_DE_VOLCAN_BUENOS_AIRES_DE_PUNTARENAS) [Accessed: 1 February 2019].
- Castillo LE, De La Cruz E, Ruepert C. 1997. Ecotoxicology and pesticides in tropical aquatic ecosystems of Central America. *Environmental Toxicology and Chemistry* 16: 41–51.
- Chaves G, García-Rodríguez A, Mora A, Leal A. 2009. A new species of dink frog (Anura: Eleutherodactylidae: *Diasporus*) from Cordillera de Talamanca, Costa Rica. *Zootaxa* 2088: 1–14.
- Colli GR, Bastos RP, Araújo AFB. 2002. The character and dynamics of the Cerrado herpetofauna. Pp. 223–241 In: *The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna*. Editors, Oliveira PS, Marquis RJ. Columbia University Press, New York, New York, USA. 409 p.
- Coloma LA, Ron SR, Jungfer K, Grant T, Cisneros-Heredia DF, Solís F, Ibáñez R, Chaves G, Savage JM, Jaramillo C, et al. 2008. *Gastrotheca cornuta*. *The IUCN Red List of Threatened Species* 2008: e.T55329A11294031.
- Crump ML, Scott N. 1994. Visual encounter surveys. Pp. 84–92 In: *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*. Editors, Heyer WR, Donnelly MR, McDiarmid RW, Hayek LC, Foster MS. Smithsonian Institution Press, Washington, DC, USA. 364 p.
- Dixo M, Martins M. 2008. Are leaf-litter frogs and lizards affected by edge effects due to forest fragmentation in Brazilian Atlantic forest? *Journal of Tropical Ecology* 24(5): 551–554.
- Donnelly M, Guyer C. 1994. Patterns of reproduction and habitat use in an assemblage of Neotropical hylid frogs. *Oecologia* 98: 291–302.
- Duellman WE. 1970. *Hylid Frogs of Middle America*. Monographs of the Museum of Natural History. University of Kansas, Lawrence, Kansas, USA. 448 p.
- Duellman WE. 1978. The biology of an equatorial herpetofauna in Amazonian Ecuador. *Miscellaneous Publications, University of Kansas, Museum of Natural History* 65: 1–352.
- Duellman WE. 1999a. Distribution patterns of amphibians in South America. Pp. 255–328 In: *Patterns of Distribution of Amphibians. A Global Perspective*. Editor, Duellman WE. The Johns Hopkins University Press, Baltimore, Maryland, USA. 648 p.
- Duellman WE. 1999b. *Patterns of Distribution of Amphibians. A Global Perspective*. The Johns Hopkins University Press, Baltimore, Maryland, USA. 648 p.
- Duellman WE. 2001. *Hylid Frogs of Middle America*. New edition. Society for the Study of Amphibians and Reptiles, Ithaca, New York, USA. 1,170 p.

- Duellman WE. 2005. *Cusco Amazónico. The Lives of Amphibians and Reptiles in an Amazonian Rainforest*. Cornell University Press, Ithaca, New York, USA. 433 p.
- Faivovich J, Pereyra MO, Luna MC, Hertz A, Blotto BL, Vásquez-Almazán CR, McCranie JR, Sánchez DA, Baêta D, Araujo-Viera K, et al. 2018. On the monophyly and relationships of several genera of Hylini (Anura: Hylidae: Hylinae), with comments on recent taxonomic changes in hylids. *South American Journal of Herpetology* 13: 1–33.
- Ferreira GC, Sturaro MJ, Peloso PLV. 2017. Amphibians and reptiles from Floresta Nacional de Pau-Rosa, Amazonas, Brazil: an important protected area at the heart of Amazonia. *Acta Amazonica* 47: 259–268.
- Frost DR. 2019. Amphibian species of the World: an online reference. Version 6.0. American Museum of Natural History, New York, New York, USA. Available: <http://research.amnh.org/herpetology/amphibia/index.html> [Accessed: 16 March 2019].
- Funk WC, Caminer M, Ron SR. 2012. High level of cryptic species diversity uncovered in Amazonian frogs. *Proceedings of the Royal Society B, Biological Sciences* 279: 1,806–1,814.
- García-Rodríguez A, Chaves G, Benavides-Varela C, Puschendorf R. 2011. Where are the survivors? Tracking relictual populations of endangered frogs in Costa Rica. *Diversity and Distributions* 18: 204–212.
- Gray AR, Bland AW. 2016. Notes on the reproduction of the endemic Costa Rican toad, *Incilius chompipe* (Anura: Bufonidae). *Mesoamerican Herpetology* 3(2): 464–467.
- Guyer C, Donnelly MA. 2005. *Amphibians and Reptiles of La Selva, Costa Rica, and the Caribbean Slope*. University of California Press, Berkeley, California, USA. 420 p.
- Haddad CF, Prado CP. 2005. Reproductive modes in frogs and their unexpected diversity in the Atlantic Forest of Brazil. *The American Institute of Biological Sciences Bulletin* 55(3): 207–217.
- Hayes MP, Pounds J, Timmerman WW. 1989. An annotated list and guide to the amphibians and reptiles of Monteverde, Costa Rica. *Herpetological Circular* 17: 1–67.
- Hertz A, Hauenschild F, Lotzkat S, Köhler G. 2012. A new golden frog species of the genus *Diasporus* (Amphibia, Eleutherodactylidae) from the Cordillera Central, western Panama. *ZooKeys* 196: 23–46.
- Hof C, Araújo MB, Jetz W, Rahbek C. 2011. Additive threats from pathogens, climate, and land-use change for global amphibian diversity. *Nature* 480: 516–519.
- Holdridge LR. 1967. *Life Zone Ecology*. Revised edition. Tropical Science Center, San José, Costa Rica. 149 p.
- IUCN. 2019. The IUCN Red List of Threatened Species. Version 2018-1. Available: <http://www.iucnredlist.org> [Accessed: 23 November 2019].
- IUCN SSC Amphibian Specialist Group. 2019. *Ecnomiohyla veraguensis*. The IUCN Red List of Threatened Species 2019: e.T85341790A90129135.
- Kubicki B. 2007. *Glass Frogs of Costa Rica*. Editorial INBIO, San José, Costa Rica. 304 p.
- Kubicki B. 2008. Amphibian diversity in Guayacán, Limón province, Costa Rica. *Brenesia* 69: 35–42.
- Kubicki B, Salazar S. 2015. Discovery of the golden-eyed fringe-limbed treefrog, *Ecnomiohyla bailarina* (Anura: Hylidae), in the Caribbean foothills of southeastern Costa Rica. *Mesoamerican Herpetology* 2: 76–86.
- La Marca E, Lips KR, Lötters S, Puschendorf R, Ibáñez R, Rueda-Almonacid JV, Schulte R, Marty, C, Castro F, Manzanilla-Puppo J, et al. 2005. Catastrophic population declines and extinctions in neotropical harlequin frogs (Bufonidae: *Atelopus*). *Biotropica* 37: 190–201.
- Laurencio D, Malone JH. 2009. The amphibians and reptiles of Parque Nacional Carara, a transitional herpetofaunal assemblage in Costa Rica. *Herpetological Conservation and Biology* 4: 120–131.
- Leenders T. 2016. *Amphibians of Costa Rica. A Field Guide*. Zona Tropical Press, Ithaca, New York, USA and London, United Kingdom. 531 p.
- Lehtinen RM, Lannoo MJ, Wassersug RJ. 2004. Phytotelm-breeding anurans: past, present, and future research. *Miscellaneous Publications, Museum of Zoology, University of Michigan* 193: 1–9.
- Lima JD. 2008. A herpetofauna do Parque Nacional do Montanhas do Tumucumaque, Amapá, Brasil, Expedições I a V. Pp. 38–50 In: *Inventários Biológicos Rápidos no Parque Nacional Montanhas do Tumucumaque, Amapá, Brasil*. RAP Bulletin of Biological Assessment 48. Editor, Bernard E. Conservation International, Arlington, Virginia, USA. 151 p.
- Lima JRF, Lima JD, Lima SD, Silva RBL, Andrade GV. 2017. Amphibians found in the Amazonian Savanna of the Rio Curiaú Environmental Protection Area in Amapá, Brazil. *Biota Neotropica* 17: e20160252.
- Lips KR, Green DE, Papendick R. 2003. Chytridiomycosis in wild frogs from southern Costa Rica. *Journal of Herpetology* 37: 215–218.
- Lopes-Santos D, Pereira S, Edmar-Pereira V, Vaz-Silva W. 2014. Amphibians and reptiles from southeastern Goiás, central Brazil. *Check List* 10(1): 131–148.
- Lynch JD. 2005. Discovery of the richest frog fauna in the world – an exploration of the forest to the north of Leticia. *Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales* 29(113): 581–588.
- McDiarmid RW, Savage JM. 2005. The herpetofauna of the Rincón area, Península de Osa, Costa Rica, a Central American lowland evergreen forest site. Pp. 366–427 In: *Ecology and Evolution in the Tropics, a Herpetological Perspective*. Editors, Donnelly

- MA, Crother BI, Guyer C, Wake MH, White ME. University of Chicago Press, Chicago, Illinois, USA. 675 p.
- Morales VR, McDiarmid RW. 1996. Annotated checklist of the amphibians and reptiles of Pakitza, Manu National Park Reserve Zone, with comments on the herpetofauna of Madre de Dios, Peru. Pp. 503–522 In: *The Biodiversity of Southeastern Peru*. Editors, Wilson DE, Sandoval A. Smithsonian Institution Press, Washington, DC, USA. 679 p.
- Myers CW. 1969. Ecological geography of cloud forest in Panama. *American Museum of Natural History Novitates* 2372: 1–28.
- NatureServe, IUCN SSC Amphibian Specialist Group. 2013. *Duellmanohyla uranochroa*. *The IUCN Red List of Threatened Species* 2013: e.T55314A3028798.
- Nogueira C, Colli GR, Martins M. 2009. Local richness and distribution of the lizard fauna in natural habitats of the Brazilian Cerrado. *Austral Ecology* 34: 83–96.
- Peloso PLV. 2010. A safe place for amphibians? A cautionary tale on the taxonomy and conservation of frogs, caecilians, and salamanders in the Brazilian Amazonia. *Zoologia* 27: 667–673.
- Pereira-Júnior AP, Costa-Campos CE, Araújo AS. 2013. Composição e diversidade de anfíbios anuros do campus da Universidade Federal do Amapá. *Biota Amazônia* 3(1): 13–21.
- Pounds JA, Fogden MPL, Campbell JH. 1999. Biological response to climate change on a tropical mountain. *Nature* 398: 611–615.
- Pounds JA, Bustamante MR, Coloma LA, Consuegra JA, Fogden MPL, Foster PN, La Marca E, Masters KL, Merino-Viteri A, Puschendorf R, et al. 2006. Widespread amphibian extinctions from epidemic disease driven by global warming. *Nature* 439: 161–167.
- Pounds J, Bolaños F, Solís F, Ibáñez R, Chaves G, Savage JM, Jaramillo C, Fuenmayor Q. 2008a. *Pristimantis altae*. *The IUCN Red List of Threatened Species* 2008: e.T56406A11470632.
- Pounds J, Bolaños F, Solís F, Ibáñez R, Chaves G, Savage JM, Jaramillo C, Fuenmayor Q, Castro F, Grant T, et al. 2008b. *Pristimantis caryophyllaceus*. *The IUCN Red List of Threatened Species* 2008: e.T56497A11475825.
- Puschendorf R, Hoskin CJ, Cashins SD, McDonald K, Skerratt LF, Vanderwal J, Alford RA. 2011. Environmental refuge from disease-driven amphibian extinction. *Conservation Biology* 25: 956–964.
- Queiroz SS, Silva AR, Reis FM, Lima JD, Lima JRF. 2011. Anfíbios de uma área de castanhal da Reserva Extrativista do Rio Cajari, Amapá. *Biota Amazônia* 1: 1–18
- Ron SR, Merino-Viteri A, Ortiz A. 2018. *Anfíbios del Ecuador*. Museo de Zoología, Pontificia Universidad Católica del Ecuador, Quito, Ecuador. Available: <https://bioweb.bio/faunaweb/amphibiaweb> [Accessed: 23 November 2019].
- Rovito SM, Devitt TJ, Devitt SC. 2015. First survey of the amphibians and reptiles of the Nectandra Cloud Forest Reserve, Alajuela, Costa Rica. *Check List* 11: 1,570.
- Ryan MJ, Scott NJ, Cook JA, Willink B, Chaves G, Bolaños F, Garcia-Rodriguez A, Latella IM, Koerner SE. 2015. Too wet for frogs: changes in a tropical leaf litter community coincide with la Niña. *Ecosphere* 6(1): 1–10.
- Salazar S. 2015. Redescubrimiento de la rana marsupial *Gastrotheca cornuta* (Anura: Hemiphractidae) en Costa Rica. *Brenesia* 83–84: 81–82.
- Santos-Barrera G, Pacheco J, Mendoza-Quijano F, Bolaños F, Chaves G, Daily GC, Ehrlich PR, Ceballos G. 2008. Diversity, natural history, and conservation of amphibians and reptiles from the San Vito Region, southwestern Costa Rica. *Revista de Biología Tropical* 6: 755–778.
- Schluter A, Icochea J, Pérez JM. 2004. Amphibians and reptiles of the lower Río Lullapichis, Amazonian Peru: updated species list with ecological and biogeographical notes. *Salamandra* 40(2): 141–160.
- Sasa M, Solórzano A. 1995. The reptiles and amphibians of Santa Rosa National Park, Costa Rica, with comments about the herpetofauna of xerophytic areas. *Herpetological Natural History* 3: 113–126.
- Sasa M, Chaves G, Porras LW. 2010. Costa Rica's herpetofauna: conservation status and future perspectives. Pp. 510–603 In: *Conservation of Mesoamerican Amphibians and Reptiles*. Editors, Wilson LD, Townsend JH, Johnson JD. Eagle Mountain Publishing, Eagle Mountain, Utah, USA. 812 p.
- Savage JM. 2002. *The Amphibians and Reptiles of Costa Rica: a Herpetofauna between Two Continents, between Two Seas*. University of Chicago Press, Chicago, Illinois, USA and London, United Kingdom. 934 p.
- Scott NJ. 1976. The abundance and diversity of the herpetofauna of tropical forest litter. *Biotropica* 8: 41–58.
- Seber GAF. 1986. A review of estimating animal abundance. *Biometrics* 42: 267–292.
- SINAC. 2018. *Plan de manejo, Parque internacional la Amistad - Talamanca*. Sistema Nacional de Áreas de Conservación, San Jose, Costa Rica. Available: <http://www.sinac.go.cr/ES/planmanejo/Plan%20Manejo%20ACLAC/Parque%20Internacional%20La%20Amistad.pdf> [Accessed: 5 January 2019].
- Solís F, Ibáñez R, Savage JM, Jaramillo C, Fuenmayor Q, Kubicki B, Pounds J, Chaves G, Jungfer K, Lips K. 2008. *Agalychnis lemur*. *The IUCN Red List of Threatened Species* 2008: e.T55855A11381418.
- Solórzano A, Lamar WW, Porras L. 1998. The marsupial frog (*Gastrotheca cornuta*; Amphibia, Hylidae) in Isthmian Central America. *Revista Biología Tropical*

45(4): 1,675–1,677.

- Streicher JW, Crawford AJ, Edwards CW. 2009. Multilocus molecular phylogenetic analysis of the montane *Craugastor podiciferus* species complex (Anura: Craugastoridae) in Isthmian Central America. *Molecular Phylogenetics and Evolution* 53: 620–630.
- Stuart SN, Chanson JS, Cox NA, Young BE, Rodrigues ASL, Fischman DL, Waller RW. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* 306: 1,783–1,786.
- Vaz-Silva W, Oliveira RM, Gonzaga AFN, Pinto KC, Poli CF, Bilce TM, Penhacek M, Wronski L, Martin J, Junqueira TG, et al. 2015. Contributions to the knowledge of amphibians and reptiles from Volta Grande do Xingu, northern Brazil. *Brazilian Journal of Biology* 75: 205–218.
- Verdade VK, Valdujo PH, Carnaval AC, Schiesari L, Toledo LF, Mott T, Andrade GV, Eterovick PC, Menin M, Pimenta BV, et al. 2012. A leap further: the Brazilian Amphibian Conservation Action Plan. *Alytes* 29: 28–43.
- Wake DB, Vredenburg VT. 2008. Colloquium paper: Are we in the midst of the sixth mass extinction? A view from the world of amphibians. *Proceedings of the National Academy of Sciences of the United States of America* 105: 11,466–11,473.
- Wake DB. 1987. Adaptive radiation of salamanders in Middle American cloud forests. *Annals of the Missouri Botanical Garden* 74(2): 242–264.
- Wells KD. 2007. *The Ecology and Behavior of Amphibians*. The University of Chicago Press, Chicago, Illinois, USA. 1,148 p.
- Whitfield SM, Bell KE, Philippi T, Sasa M, Bolaños F, Chaves G, Savage JM, Donnelly MA. 2007. Amphibian and reptile declines over 35 years at La Selva, Costa Rica. *Proceedings of the National Academy of Sciences of the United States of America* 104(20): 8,352–8,356.
- Whitfield SM, Alvarado G, Abarca J, Zumbado H, Zuñiga I, Wainwright M, Kerby J. 2017. Differential patterns of *Batrachochytrium dendrobatidis* infection in relict amphibian populations following severe disease-associated declines. *Diseases of Aquatic Organisms* 126: 33–41.
- Young BE, Lips KR, Reaser JK, Ibanez R, Salas AW, Cedeño JR, Coloma LA, Ron S, La Marca E, Meyer JR, et al. 2001. Population declines and priorities for amphibian conservation in Latin America. *Conservation Biology* 15: 1,213–1,223.
- Zimmerman BL, Rodrigues MT. 1990. Frogs, snakes, and lizards for the INPA-WWF Reserves near Manaus, Brazil. Pp. 426–454 In: *Four Neotropical Rainforests*. Editor, Gentry AH. Yale University Press, New Haven, Connecticut, USA and London, United Kingdom. 627 p.

**José Andrés Salazar-Zúñiga** is a biologist and M.Sc. student in the Department of Ecology at Universidad Autónoma de Madrid and Universidad Complutense de Madrid, Spain. He is a professor of herpetology and an active researcher of the Herpetology Department of the University of Costa Rica, and research coordinator of the Veragua Foundation, Limón, Costa Rica (NGO). José's research interests include animal behavior, natural history, and conservation of amphibians and reptiles. He has participated in several conservation workshops organized by the Amphibian Specialist Group and the University of Costa Rica, including the workshops to review the IUCN Red List of amphibians of Costa Rica and for elaborating the amphibian conservation strategy for Mesoamerica. José is an active conservationist who participates in different environmental education programs in rural communities, and he is currently developing different research and conservation projects with various species of the Centrolenidae, Dendrobatidae, and Hylidae families.



**Wagner Chaves-Acuña** is a Ph.D. student in the Department of Biodiversity and Experimental Biology at Universidad de Buenos Aires, Argentina, and a fellow of Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) at the Museo Argentino de Ciencias Naturales "Bernardino Rivadavia," Argentina (MACN). Wagner is also an associated researcher at Veragua Foundation, where he has conducted research on bioacoustics and behavior of dendrobatids and centrolenids. His current research interests include systematics, taxonomy, and evolution of hylids, as well as conservation projects with critically endangered species of anurans.



**Gerardo Chaves** is a biologist from the University of Costa Rica. Gerardo's degree thesis focused on the arrivals of the Olive Ridley Sea Turtles, but most of his professional work has focused on the ecology and taxonomy of the Costa Rican herpetofauna. Since 1992, his research activity has focused on understanding the decline of amphibian populations in Mesoamerica and on filling the herpetofauna inventory gaps in several areas of Costa Rica, mainly across the Talamanca Mountain Range. Since 1997, Gerardo has worked in the Museum of Zoology of the University of Costa Rica in the herpetofauna collection. He has published several journal articles related to the ecology and taxonomy of Neotropical herpetofauna. His conservation efforts are related to the sustainable use of the sea turtle eggs project on "arribadas" and collaboration with IUCN in the evaluation of the Red List for Costa Rica and Mesoamerica, for both reptiles and amphibians. Gerardo is currently chair of the IUCN Amphibian Specialist Group in Costa Rica.



## Extreme frog diversity in Costa Rica



**Alejandro Acuña** is a professional in Ecotourism Management, and he has worked as a coordinator of biodiversity projects in several national parks with the National System of Conservancy Areas (SINAC). Alejandro is a naturalist guide at Veragua Rainforest and research assistant of the Veragua Foundation.



**Juan Ignacio Abarca-Odio** is a biologist from the University of Costa Rica, where he collaborates as a researcher in the Aquatic Experimentation Laboratory (CIMAR) and the Laboratory for Experimental and Comparative Pathology (LAPECOM). Juan's main interests are on the effects of climate change on the ecology and physiology of vulnerable organisms such as anthozoans, arthropods, amphibians, and reptiles. He also has great interest in data science.



**Javier Lobon-Rovira** is a Wildlife Photographer and a Ph.D. student at the CIBIO-InBio institution in Portugal. Javier has assisted as an Animal Care Volunteer at Wildlife Rescue Association (Vancouver, British Columbia, Canada) rehabilitating wildlife and promoting the welfare of wild animals in the urban environment. He has worked as a field assistant with Moose and Wolves in Utah, and sampling fishes using electric-fishing techniques. For his Master's thesis, Javier identified a "lost population" of Iberian Lynx by anecdotal occurrence data and molecular scatology, which formed a major part of his M.Sc. degree. Furthermore, he has collaborated on many different herpetology and conservation projects. Currently, his Ph.D. project focuses on the systematics and evolution of geckonids from Southern Africa, which includes the descriptions of species and the identification of several evolutionary hypotheses within this group.



**Edwin Gómez-Méndez** is biologist from the University of Costa Rica. Edwin has work as an Environmental Manager in several important national projects, such as the Reventazón Hydroelectric Project, expansion of the National Route 32, and the Costa Rica-Panamá Binational Bridge. Edwin is a Biology professor at Florencia del Castillo University, Costa Rica. His research interests concern the conservation of amphibians and reptiles.



**Ana Cecilia Gutiérrez-Vannucchi** is a biologist and M.Sc. student at the School of Biology of the University of Costa Rica, where she is part of the Laboratory of Urban Ecology and Animal Communication (LEUCA). Ana's research interests are in ecology, bioacoustics, and animal behavior. Her most recent projects have focused on studying the possible effects of urban noise on the acoustic communication of anurans.



**Federico Bolaños** is a professor of Herpetology at the School of Biology of the University of Costa Rica, curator of the Herpetology collection at Museo de Zoología, and a member of the International Union for Conservation and Nature (Amphibian, Conservation Breeding, and Viper Specialist Groups). Federico's M.Sc. dissertation focused on the natural history and population ecology of *Oophaga granulifera*. His primary interest involves the behavioral ecology of amphibians, but he has also participated in taxonomic studies, including the description of nine species of amphibians. Federico became a professor when amphibian declines were first being detected and has since dedicated most of his research efforts to this topic. He has mentored more than 35 graduate students in Biology at UCR. He has authored more than 70 publications, including book chapters and peer reviewed papers in scientific journals, and has served as a book editor.