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NOTES ON GEOGRAPHIC DISTRIBUTION

First record of *Plectrohyla guatemalensis* Brocchi, 1877 (Anura, Hylidae) from Nicaragua

Celsa Señaris[1], Javier Sunyer[2, 3]

1 *Estación Biológica de Doñana, Avenida Américo Vespucio 26, 41092, Seville, Spain*
2 *Associate Researcher, Museo Herpetológico de la Universidad Nacional Autónoma de Nicaragua – León, León, Nicaragua*
3 *International Union for Conservation of Nature, Amphibian Specialist Group, León, Nicaragua*

Corresponding author: *Celsa Señaris (celsisenaris@ebd.csic.es)*

Abstract. We confirm the presence of the genus *Plectrohyla* Brocchi, 1877 in Nicaragua and report the first records of *Plectrohyla guatemalensis* Brocchi, 1877 in the country based on three specimens collected in 1983 from the central mountain range of Matagalpa department. These specimens collected over 40 years ago are the southernmost records for the species and expand its geographic distribution by approximately 175 km southeast from its nearest recorded locality in Honduras.

Key words. Amphibian, Central America, distribution extension, museum collections, Spikethumb Frog, threatened genus

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INTRODUCTION

Plectrohyla Brocchi, 1877 is an arboreal tree-frog genus composed of 19 species and distributed in the highlands (900–2800 m a.s.l.) of northern Central American, from Chiapas, Mexico, through Guatemala and northern El Salvador to east-central and northern Honduras (Köhler 2011; Frost 2024). Members of this genus inhabit cold streams and ravines in montane pine–oak forests and cloud forests, and most have relatively small or fragmented geographic distributions (Duellman and Campbell 1992; Duellman 2001; McCranie and Wilson 2002; Köhler 2011).

Plectrohyla is considered a highly threatened linage. According to the IUCN Red List, 89.5% of its species are considered Critically Endangered (8 spp.), Endangered (7 spp.), or Vulnerable (2 spp.), and one species, *Plectrohyla guatemalensis* Brocchi, 1877, is categorized as Near Threatened but close to qualifying as Vulnerable (IUCN 2024). Only *Plectrohyla matudai* Hartweg, 1941 is listed as Least Concern in view of its relatively wide distribution, tolerance of some habitat modification, and a presumed large and stable population. Over the last decades, most of the species of this genus have declined for a variety of reasons including habitat loss and degradation, aquatic and terrestrial pollution, chytridiomycosis, and, more recently, an increase in the frequency and intensity of extreme weather events (e.g. droughts and torrential rains) resulting from climate change (Corey 2010; Kolby et al. 2010; López-Méndez and Aranda-Coello 2021; IUCN 2024). For these reasons *Plectrohyla* is among the top 10 most threatened frog genera in the world (Re:wild et al. 2023). All new information about any species in this genus is important, both to update its risk of extinction in more detail and to establish conservation actions.

Köhler (2000, 2001, 2011) recorded *Plectrohyla* sp. from Nicaragua based on two undetermined larval and subadult specimens (SMF 79360-61) photographed and collected in April 1999 in the cloud forest of "Parque Nacional Saslaya, Campamento Los Monos (13.7516, −85.0366), 800 m [a.s.l.], departamento Atlántico Norte, about 20 m away from the nearest stream". However, several herpetological compilations from Nicaragua do not include this genus in the country (i.e. Ruiz and Buitrago 2003; Sunyer 2014; HerpetoNica 2015; Robleto-Hernández et al. 2017). To date, no other records or information is available to confirm the presence of *Plectrohyla* in Nicaragua (McCranie et al. 2019).

During the revision of the herpetological collection of the Estación Biológica de Doñana, Spain, we found three specimens of *Plectrohyla* collected in the Nicaraguan department of Matagalpa in March and April 1983. Herein, we confirm the presence of this genus in Nicaragua and report for the first time *P. guatemalensis* from the country. These records expand its geographic distribution southeast from its nearest recorded locality in Honduras, and we provide an updated distribution map for this species.

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METHODS

The voucher specimens are deposited at the Herpetological Collection of Estación Biológica de Doñana (**EBD-CSIC**) in Seville, Spain. The species was identified using the descriptions by Duellman and Campbell (1992), Duellman (2001), McCranie and Wilson (2002), and McCranie (2017). Morphological terminology and abbreviations of the morphometric traits follow McCranie (2017). Measurements were taken with digital calipers to the nearest 0.01 mm as follows: SVL = snout–vent length; HL = head length; HW = head width; IOD = interorbital distance at midlength of upper eyelid; SL= snout length, distance from anterior edge of orbit to tip of snout; EL = eye length; EW = width of upper eyelid; DW = third finger disc width; FEL = femur length; SHL = shank length (tibia); FL = foot length, distance from proximal edge of inner metatarsal tubercle to tip of longest toe; FIL = finger I length, from base of distal subarticular tubercle to tip of digit; OSL = outer prepollex length, from base to tip; and PL = prepollical length from base of beginning of inner prepollex to outer base of outer prepollex.

To provide an updated distribution of this species, we gathered *Plectrohyla guatemalensis* occurrence data from Global Biodiversity Information Facility (GBIF 2024), literature, and the new records from Nicaragua. The final map of the currently known distribution of the species was constructed on a cartographic base of countries from IUCN (2024), a 90-m resolution digital elevation model (https://srtm.csi.cgiar.org/), and the occurrence records processed with ESRI ArcGIS Desktop v. 10.8.2.

RESULTS

Order Anura
Family Hylidae

***Plectrohyla guatemalensis* Brocchi, 1877**
Figures 1–3

New records. NICARAGUA — Departamento de Matagalpa • Santa María de Ostuma; [13.0054, −85.9255]; 1400 m elev.; 24.III.1983; Juan Carlos Martínez-Sánchez leg.; 1 ♂, EBD 28467H. • Same locality and date; 1 juvenile, EBD 28468H • Fila El Porvenir, 2 km north east of Santa María de Ostuma; [13.016, −85.9073]; 1600 m elev.; 21.IV.1983; Juan Carlos Martínez-Sánchez leg.; 1 ♂, EBD 28469H.

Adult male EBD 28467H (live weight 14 g) and juvenile EBD 28468H (2.4 g) were found in tropical rainforest, the latter on leaves of a banana plant (*Musa sapientum* L.) in a disturbed area in the forest. The adult male EBD 28469H (8.1 g) was found on moss on a tree branch, about 2 m above the ground (field notes, Juan Carlos Martínez-Sánchez, 1983) (Figure 1, 2).

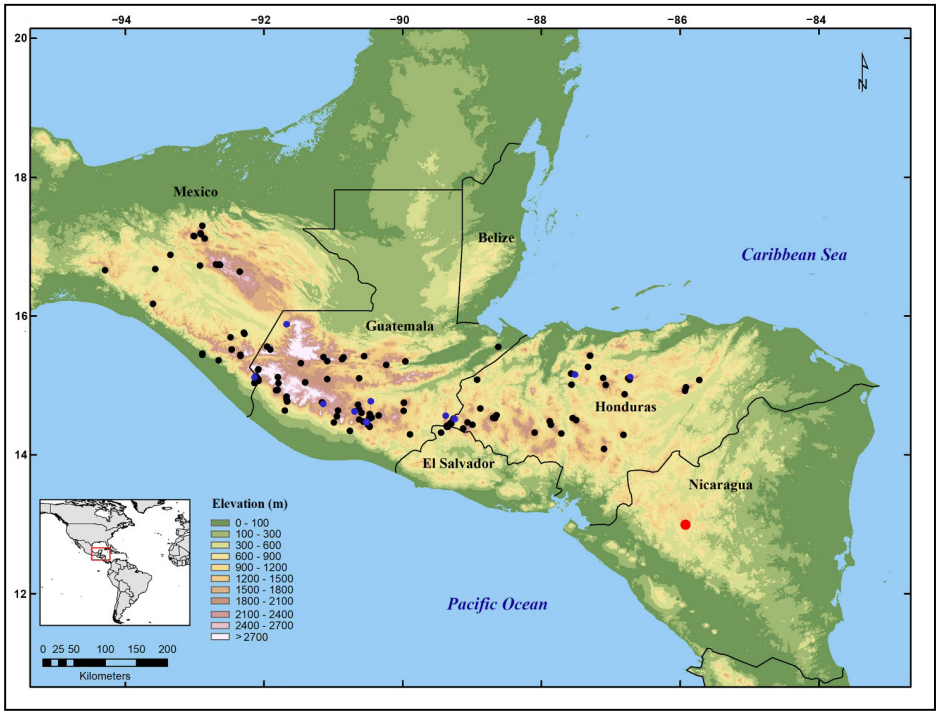

Figure 1. Distribution of *Plectrohyla guatemalensis*. Black points = literature records and museum specimen occurrence data available in GBIF (2024); blue points = observations occurrence data in GBIF (2024); red point = new records presented in this study.

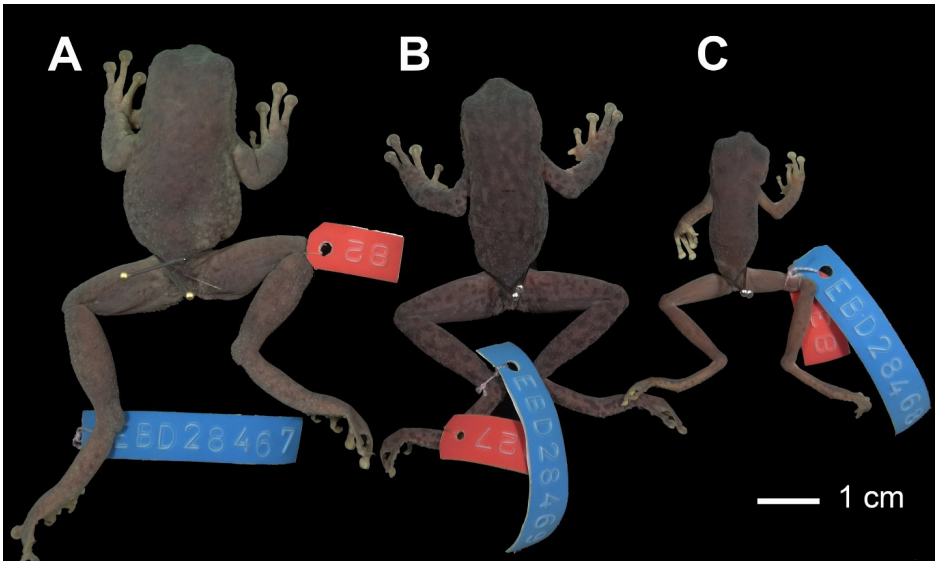

Figure 2. Dorsal view of preserve specimens of *Plectrohyla guatemalensis* from Santa María de Ostuma, Matagalpa department, Nicaragua. **A.** EBD 28467H, adult male. **B.** EBD 28469H, adult male. **C.** EBD 28468H, juvenile.

Identification. We identified these specimens as *P. guatemalensis* since their coloration in preservative, external morphology, and morphometric data (Table 1) are congruent with the descriptions and accounts provided by Duellman (2001), McCranie and Wilson (2002), and McCranie (2017). The most relevant traits for the identification of these specimens are: 1) massive bifid prepollex (Figure 3); 2) vocal slits absent; 3) short snout, semicircular in dorsal view and semicircular to near vertical in profile (Figure 4A, B); 4) dorsal surfaces (head, back, and limbs) with numerous well development rounded tubercles (Figure 4C); 5) coarsely aerolate ventral skin including throat and chest; 6) adult males brown or tan brown, with darker brown markings on dorsal surfaces; no cream vertical bars on anterior and posterior surfaces of thighs (Figure 2); flanks slightly paler than dorsal surfaces, with contrasting darker markings; 7) belly and ventral pale brown, with chin and throat slightly to heavily mottled with dark brown; and 8) medium-sized with SVL in adult males 48.34 and 52.65 mm.

Of the 19 species currently in this genus (Frost 2024), seven exhibit bifid prepollex: *Plectrohyla acanthodes* Duellman & Campbell, 1992 (Meseta Central de Chiapas in Mexico and slopes of the adjacent Sierra de los Cuchumatanes in western Guatemala, 1540–2250 m), *P. calvata* McCranie, 2017 (slopes of Montaña de Celaque in Honduras, 1900–2500 m), *P. exquisite* McCranie & Wilson, 1998 (Sierra de Omoa in extreme northwestern Honduras, between 1490–1680 m), *P. guatemalensis* (with an extended distribution

Table 1. Measurements (mm) of the specimens of *Plectrohyla guatemalensis* from Matagalpa department, Nicaragua. For character abbreviations see methods.

Characters	Specimen		
	EBD 28467H	**EBD 28469H**	**EBD 28468H**
Sex	♂	♂	Juvenile
SVL	52.65	48.34	33.80
HL	18.81	16.03	12.28
HW	17.51	15.39	12.08
IOD	7.11	6.48	4.46
SL	4.81	4.37	3.53
EL	6.90	5.77	5.34
EW	4.53	4.51	3.67
DW	3.30	3.10	—
FEL	28.71	24.63	16.62
SHL	29.31	27.80	19.16
FL	25.34	24.24	15.72
FIL	3.97	3.69	2.76
OSL	2.95	2.77	0.69
PL	3.89	3.62	2.03

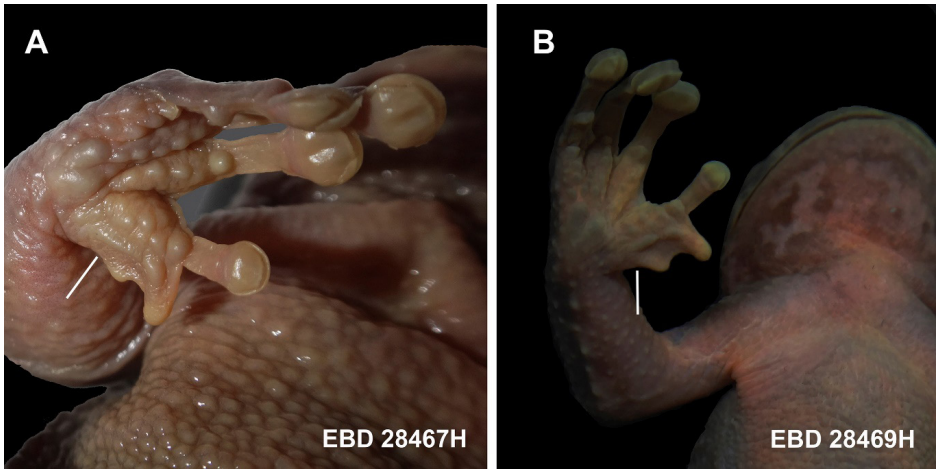

Figure 3. Detail view of bifid prepollex and coarsely aerolate chest region of preserve specimens of *Plectrohyla guatemalensis* from Matagalpa department, Nicaragua. **A.** EBD 28467H, adult male. **B.** EBD 28469H, adult male; note throat heavily mottled with darker brown markings. The white lines point the basal beginning of prepollex.

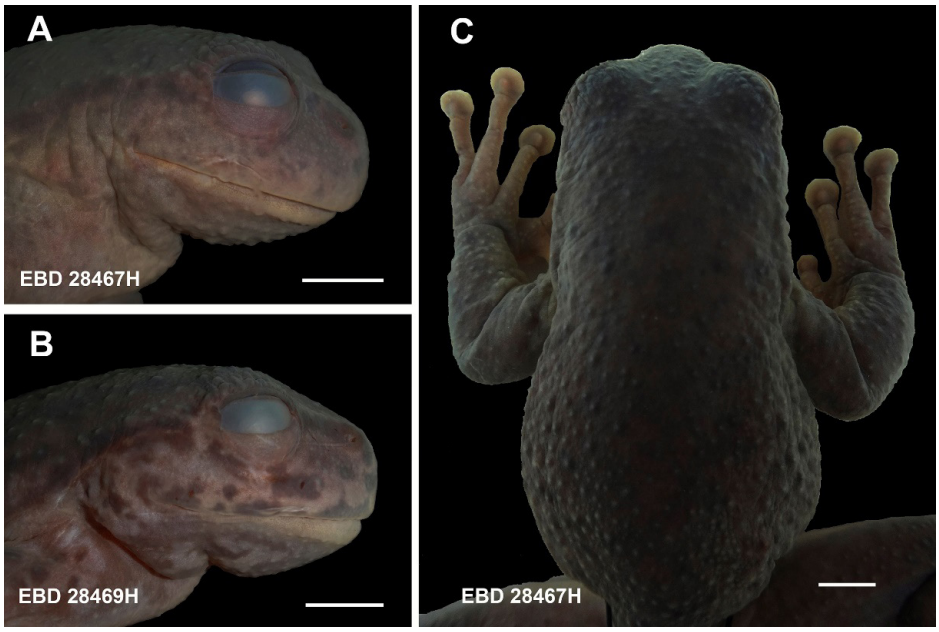

Figure 4. Lateral view of heads and dorsal skin of preserve specimens of *Plectrohyla guatemalensis* from Matagalpa department, Nicaragua. **A.** Snout semicircular, slightly mottled with dark brown markings. **B.** Snout near vertical in profile, heavily mottled with dark brown markings. **C.** Dorsal skin with well development rounded tubercles. Scale bars = 0.5 cm.

from highlands of the Sierra Madre from southeastern Chiapas, Mexico, eastward through the central and southwestern highlands of Guatemala to northwestern El Salvador and the Sierra de Nombre de Dios in north-central Honduras, 900–2800 m), *P. hartwegi* Duellman, 1968 (disjunct distribution in Sierra Madre de Chiapas and eastern Oaxaca in Mexico, slopes of the Sierra de Cuchumatanes, mountains in El Quiché, and Sierra de las Minas in Guatemala, and Sierra de Omoa in southwestern Honduras, 925–2700 m), *P. pokomchi* Duellman & Campbell, 1984 (Sierra de las Minas and Sierra de Xucaneb in Guatemala, 1400–2120 m), and *P. teuchestes* Duellman & Campbell, 1992 (at 1000 m in Sierra de Xucaneb in Guatemala).

The Nicaraguan specimens of *Plectrohyla guatemalensis* reported here are distinguished from *P. pokomchi* by the absence of vocal slits in adult males, and from *P. hartwegi* by the absent of dark (black) with cream (usually vertical) marks in anterior and posterior surfaces of thighs. They also differ from *P. exquisite* and *P. teuchestes* in having a tuberculate dorsal surfaces (vs. a smooth or almost smooth dorsum). *Plectrohyla acanthodes* have large, conical tubercles on dorsal surfaces, while the specimens from Nicaragua have the dorsal surfaces more densely tuberculate and with rounded tubercles. Additionally, *P. acanthodes*, *P. exquisite*, *P. hartwegi*, and *P. teuchestes* are notably larger (SVL > 67 mm) than the new recorded Nicaraguan *P. guatemalensis* specimens. Finally, the most recently described species of the genus, *P. calvata*, has a dorsal coloration uniformly dark without distinctive markings and largely smooth dorsal surfaces in adult males, traits than differ from the distinctive dorsal darker marking and the tuberculate skin of *P. guatemalensis*. Additionally, the Nicaraguan specimens also differ from *P. calvata* by the presence of a massive and larger prepollex (PL/FIL 0.98 vs. 0.75–0.94 in *P. calvata*) (Figure 3), and a coarsely aerolate chest region (Figure 4A, B).

DISCUSSION

The records of *Plectrohyla* presented here are of special interest for taxonomic and conservation issues. First, the specimens identified as *Plectrohyla guatemalensis* from Santa María de Ostuma in Nicaragua confirm the presence of this genus in the country and extend the geographical distribution of this species approximately 175 km southeast from the nearest locality in Honduras.

Plectrohyla guatemalensis is a wide-ranging species, occurring in various isolated populations from south-eastern Mexico, Guatemala, El Salvador, Honduras, and now to northern Nicaragua (Figure 1). Historically, this taxon has been considered a species complex, and four new species (i.e. *P. acanthodes*, *P. teuchestes*, *P. exquisite*, and *P. calvata*) had been named for populations formerly identified as *P. guatemalensis* (Duellman and Campbell 1992; McCranie and Wilson 1998; McCranie 2017). Even now it is considered that some Honduran populations may belong to other species (McCranie 2017; IUCN SSC Amphibian Specialist Group 2020). To clearly elucidate the identity of these different geographically isolated populations, including the southernmost known Nicaraguan population recorded here, a detailed integrative and molecular approach is needed.

A recent global assessment confirmed that amphibians are the most threatened vertebrate group, with 40.7% of species threatened with extinction (Luedtke et al. 2023). In the Neotropics, notable concentrations of threatened species are located in the Caribbean, Mesoamerica, and tropical Andes, and most of the Critically Endangered anurans inhabit in highland forests of the last two regions (Re:wild et al. 2023). *Plectrohyla* is one of the top 10 most threatened frog genera, with 89% of species in extinction risk categories. *Plectrohyla guatemalensis* is categorized as Near Threatened but close to qualifying for Vulnerable because of an estimated population decline of approximately 20–25% in the last decade (IUCN SSC Amphibian Specialist Group 2020). The Guatemala Spikethumb Frog was historically abundant in Mexico, but it has not been recorded in that country for decades, except from Volcán Tacaná (IUCN SSC Amphibian Specialist Group 2020). In Honduras, it is apparently still common in some sites (e.g. Parque Nacional Montaña de Yoro, Parque Nacional Pico Pijol, and Parque Nacional La Muralla), moderately common in its Guatemalan range (González-Mollinedo and Mármol-Kattán 2020), and with few recent records in El Salvador (Morán-Hidalgo et al. 2012).

The Nicaraguan records of *P. guatemalensis* proves that the species has an even wider distribution across the mountain systems of northern Central America, at least until the early 1980s. Several clues may explain the finding of *P. guatemalensis* in Nicaragua over 40 years ago and why it has not been found since. In addition to the difficulty of detecting arboreal species in tropical forests, it is possible that this species was historically uncommon or rare in Nicaragua, only detectable with high sampling efforts. Although there has been a progressive increase in herpetological research in the country, most of the Nicaraguan departments remain understudied (Sunyer et al. 2014), particularly at high elevations, and many regions remain poorly explored (Martínez-Fonseca et al. 2024), as is the case of the Santa María de Ostuma and surrounding mountain areas.

Although several field trips were carried out to Cerro Saslaya after Köhler (2000) records of *Plectrohyla* sp., they resulted in no additional specimens for this genus (McCranie et al. 2019). However, those posterior field trips were carried out during the rainy season (May–November) (J. Sunyer unpublished data), and all *Plectrohyla* records from Nicaragua (i.e. the undetermined juveniles from Cerro Saslaya as well as our three records of *P. guatemalensis* from Santa María de Ostuma) were collected either in March or April, that is, at the end of the driest period.

Another possibility is that *P. guatemalensis* was present in the north-central mountain system of the country until the mid-1980s but is now extirpated there. Most amphibian declines have occurred in the tropics of Australia, Central America, and South America (Scheele et al. 2019; Luedtke et al. 2023). Local extirpations of anuran populations or even species extinctions in Central America have been documented since in the early 1980s (Whitfield et al. 2016; Scheele et al. 2019). Habitat loss or modification due to increases in timber harvesting, livestock, and agricultural development, pathogens, especially the chytrid fungus *Batrachochytrium dendrobatidis* Longcore, Pessier, Nichols, 1999 (*Bd*), and land and water pollution have been the most important threats to amphibians in Central America. In Nicaragua, deforestation has steadily increased over time. For example, in the La Vía Láctea territory in Matagalpa department (near the site where *P. guatemalensis* was founded in 1983), 93% of the forest cover was converted to pasture for livestock development between 1978 and 2011 (Tobar-López et al. 2019). Additionally, *Bd* is present in the country (García-Roa et al. 2014; Stark et al. 2017), and a ranavirus has been associated with an anuran mortality event in the cloud forest of Volcano Maderas in 2011 (Stark et al. 2014). *Bd* has been detected in seven *Plectrohyla* species (https://amphibiandisease.org), and apparently implicated in drastic population declines of some of its members (Corey 2010; Kolby et al. 2010). However, recent studies show that some species of the genus are apparently resistant to the effects of this fungal pathogen under field conditions (Bolom-Huet et al. 2023).

Finally, these records, housed in long-term public museums, highlight the importance of zoological collections through time and reinforce that they are timeless treasures (Koch et al. 2019), particularly in this time of rapid environmental changes, contributing to the global development of science (Nachman et al. 2023).

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ADDITIONAL INFORMATION

Conflict of interest
The authors declare that no competing interests exist.

Ethical statement
No ethical statement is reported.

Author contributions
Conceptualization: CS. Data curation: CS. Formal analysis: CS, JS. Investigation: CS, JS. Methodology: CS, JS. Resources: CS. Visualization: CS. Validation: CS, JS. Writing – original draft: CS, JS. Writing – review and editing: CS, JS.

Author ORCIDs
Celsa Señaris https://orcid.org/0000-0001-8673-7385

Data availability
All data that support the findings of this study are available in the main text.

REFERENCES

Bolom-Huet R, Pineda E, Andrade-Torres A, Díaz-Fleischer F, Muñoz AL, Galindo-González J (2023) Chytrid prevalence and infection intensity in treefrogs from three environments with different degrees of conservation in Mexico. Biotropica 55: 318–328. https://doi.org/10.1111/btp.13186

Corey SJ (2010) Phylogenetic Signal of Threatening Processes among Hylids: The Need for Clade-Level Conservation Planning. Diversity 2: 142–162. https://doi.org/10.3390/d2020142

Duellman WE (2001) Hylid frogs of Middle America. Second edition. Contributions to Herpetology 18. Society for the Study of Amphibians and Reptiles, Ithaca, New York, USA, 694 pp.

Duellman WE, Campbell JA (1992) Hylid frogs of the genus *Plectrohyla*: systematics and phylogenetic relationships. Miscellaneous Publications of the Museum of Zoology, University of Michigan 181: 1–32.

Frost DR (2024) Amphibian species of the world: an online reference. Version 6.2. American Museum of Natural History, New York, USA. https://amphibiansoftheworld.amnh.org/. Accessed on: 2024-01-06.

García-Roa R, Sunyer J, Fernández-Loras A, Bosch J (2014) First record of *Batrachochytrium dendrobatidis* in Nicaragua. Herpetological Journal 24: 65–68.

Global Biodiversity Information Facility (GBIF) (2024) *Plectrohyla guatemalensis* Brocchi, 1877. GBIF occurrence download. https://doi.org/10.15468/dl.pe8ra7. Accessed on: 2024-01-06.

González-Mollinedo S, Mármol-Kattán A (2020) The underground sex life of the Guatemalan Spike-thumb Frog (*Plectrohyla guatemalensis*). Neotropical Biology and Conservation 15: 551–559. https://doi.org/10.3897/neotropical.15.e57142

HerpetoNica (2015) Guía ilustrada de los anfibios y reptiles de Nicaragua (Herpetonicas). Ministerio de Ambiente y los Recursos Naturales (MARENA), Managua, Nicaragua, 521 pp.

IUCN SSC Amphibian Specialist Group (2020) *Plectrohyla guatemalensis*. The IUCN Red List of Threatened Species 2020: e.T121383401A53960140. https://doi.org/10.2305/iucn.uk.2020-3.rlts.t121383401a53960140.en. Accessed on: 2024-01-12.

IUCN (2024) The IUCN Red List of Threatened Species. Version 2023-1. International Union for Conservation of Nature. https://www.iucnredlist.org. Accessed on: 2024-01-06.

Koch C, Martins A, Schweiger S (2019) A century of waiting: description of a new *Epictia* Gray, 1845 (Serpentes: Leptotyphlopidae) based on specimens housed for more than 100 years in the collection of the Natural History Museum Vienna (NMW). PeerJ 7: e7411. https://doi.org/10.7717/peerj.7411

Köhler G (2000) Erste herpetologische Expedition zum Cerro Saslaya, Nicaragua. Natur und Museum 130: 61–69.

Köhler G (2001) Anfibios y reptiles de Nicaragua. Herpeton, Offenbach, Germany, 208 pp.

Köhler G (2011) Amphibians of Central America. Herpeton, Offenbach, Germany, 379 pp.

Kolby JE, Padgett-Flohr GE, Field R (2010) Amphibian chytrid fungus *Batrachochytrium dendrobatidis* in Cusuco National Park, Honduras. Diseases of Aquatic Organisms 92: 245–51. https://doi.org/10.3354/dao02055

López-Méndez AL, Aranda-Coello JM (2021) Efecto de la precipitación excesiva en una población de *Plectrohyla acanthodes* (Anura: Hylidae) en un arroyo temporal de los Altos de Chiapas, México. Mesoamericana 25: 37–46.

Luedtke JA, Chanson J, Neam K, Hobin L, Maciel AO, Catenazzi A, Borzée A, Hamidy A, Aowphol A, Jean A, Sosa-Bartuano A, Fong G A, de Silva A, Fouquet A, Angulo A, Kidov A, Muñoz Saravia A, Diesmos AC, Tominaga A, et al. (2023) Ongoing declines for the world's amphibians in the face of emerging threats. Nature 622: 308–314. https://doi.org/10.1038/s41586-023-06578-4

Martínez-Fonseca JG, Holmes IA, Sunyer J, Westeen EP, Grundler MR, Cerda PA, Fernández-Mena MA, Loza-Molina JC, Monagan IV Jr., Nondorf D, Pandelis GG, Rabosky ARD (2024) A collection and analysis of amphibians and reptiles from Nicaragua with new country and departmental records. Check List 20: 58–125. https://doi.org/10.15560/20.1.58

McCranie JR (2017) Specific status of the Montaña de Celaque Honduran frogs previously referred to as *Plectrohyla guatemalensis* (Anura: Hylidae: Hylinae). Mesoamerican Herpetology 4: 390–401.

McCranie JR, Wilson LD (2002) The amphibians of Honduras. Contributions to Herpetology Volume 19. Society for the Study of Amphibians and Reptiles, Ohio, USA, 625 pp.

McCranie JR, Sunyer J, Martínez-Fonseca JG (2019) Comments and updates to "Guía Ilustrada de Anfibios y Reptiles de Nicaragua" along with taxonomic and related suggestions associated with the herpetofauna of Nicaragua. Revista Nicaragüense de Biodiversidad 52: 3–44.

Morán-Hidalgo ES, Ruballo-Marroquín NE (2012) Nueva localidad de *Plectrohyla guatemalensis* (Brocchi, 1987) (Anura: Hylidae) en el departamento de Chalatenango, El Salvador. Revista de Biodiversidad Neotropical 2: 126–130.

Nachman MW, Beckman EJ, Bowie RC, Cicero C, Conroy CJ, Dudley R, Hayes TB, Koo MS, Lacey EA, Martin CH, McGuire JA, Patton JL, Spencer CL, Tarvin RD, Wake MH, Wang IJ, Achmadi A, Álvarez-Castañeda ST, Andersen MJ, et al. (2023) Specimen collection is essential for modern science. PLoS Biol 21: e3002318. https://doi.org/10.1371/journal.pbio.3002318

Re:wild, Synchronicity Earth, IUCN SSC Amphibian Specialist Group (2023) State of the World's Amphibians: The Second Global Amphibian Assessment. Re:wild, Texas, USA, 91 pp.

Robleto-Hernández S, Gutiérrez-Rodríguez AA, Otero Ortuño C, González EY, Leets Rodríguez L, López Guevara H, Sunyer J (2017) Libro rojo de los anfibios y reptiles de Nicaragua. Ministerio de Ambiente y los Recursos Naturales (MARENA), Managua, Nicaragua, 225 pp.

Ruiz GA, Buitrago F (2003) Guía ilustrada de la herpetofauna de Nicaragua. Ministerio de Ambiente y los Recursos Naturales (MARENA)-Agencia Española de Cooperación Internacional (AECI), Managua, Nicaragua, 331 pp.

Scheele BC, Pasmans F, Skerratt LF, Berger L, Martel A, Beukema W, Acevedo A, Burrowes PA, Carvalho T, Catenazzi A, De la Riva I, Fisher MC, Flechas SV, Foster CN, Frías-Álvarez P, Garner TWJ, Gratwicke B, Guayasamin JM, Hirschfeld M, et al. (2019) Amphibian fungal panzootic causes catastrophic and ongoing loss of biodiversity. Science 363: 1459–1463. https://doi.org/10.1126/science.aav0379

Stark T, Laurijssens C, Weterings M, Martel A, Köhler G, Pasmans F (2017) Prevalence of *Batrachochytrium dendrobatidis* in a Nicaraguan, micro-endemic Neotropical salamander, *Bolitoglossa mombachoensis*. Amphibia-Reptilia 38: 102–107. https://doi.org/10.1163/15685381-00003077

Stark T, Laurijssens C, Weterings M, Spitzen-van der Sluijs A, Martel A, Pasmans F (2014) Death in the clouds: ranavirus associated mortality in assemblage of cloud forest amphibians in Nicaragua. Acta Herpetologica 9: 125–127. https://doi.org/10.13128/acta_herpetol-13516

Sunyer J (2014) An updated checklist of the amphibians and reptiles of Nicaragua. Mesoamerican Herpetology 1: 186–202.

Sunyer J, Martínez-Fonseca JG, Salazar-Saavedra M, Galindo-Uribe DM, Obando LA (2014) Range extensions and new departmental records for amphibians in Nicaragua. Mesoamerican Herpetology 1: 164–175.

Tobar-López D, Muriel Bonin HJ, Andrade AP, Muhammad I (2019) Deforestation processes in the livestock territory of La Vía Láctea, Matagalpa, Nicaragua. Journal of Land Use Science 14: 225–241. https://doi.org/10.1080/1747423X.2019.1671907

Whitfield SM, Lips KR, Donnelly MA (2016) Amphibian Decline and Conservation in Central America. Copeia 104: 351–379. https://doi.org/10.1643/CH-15-300