Herpetology Notes, Volume 18: 1021–1025 (published online on 4 November 2025)

Passive acoustic monitoring protocol reveals new occurrence data for *Eleutherodactylus bartonsmithi* Schwartz, 1960 in eastern Cuba

Mariam Curbelo Cruz[1,2,*], Sergio L. del Castillo Domínguez[3], Leandro Galano Machado[4], and Roberto Alonso Bosch[1]

Populations of amphibians are vanishing worldwide, and with approximately 40.7% of species classified as Threatened, Endangered, or Critically Endangered they are the most threatened vertebrate group (Re: wild, Synchronicity Earth, IUCN SSC Amphibian Specialist Group, 2023). Causes of population declines include habitat loss and fragmentation, climate change, introduced species, illegal trade, and emergent diseases, including some or all in synergism (Blaustein et al., 2011; Ford et al., 2020; Pabijan et al., 2020; Luedtke et al., 2023). Many specific ecological requirements of amphibians make them increasingly vulnerable to these causes. On neotropical islands, high endemism and a limited range make species particularly vulnerable compared to continental areas (Lodge, 1993; Pitta et al., 2013; Hedges et al., 2018).

Cuba is an island with at least 71 species of frogs and toads, 94% of which are endemic (Alonso Bosch and Garcia Padron, 2017; Díaz et al., 2023) and nearly 70% of them are threatened (IUCN SSC Amphibian Specialist Group, 2023). Consequently, the need for non-invasive methodologies for studying these populations arises and, in the case of frogs, their calling activity is useful for population detection and monitoring (Benfer, 2017; Teixeira et al., 2019; Desjonquères et al., 2020). Passive acoustic monitoring (PAM) enables the simultaneous study of diverse species across temporal and spatial scales, including hard-to-access habitats. It also provides insights into ecological processes and sound-related disturbances, making it a versatile tool for studying ecosystems (Ross et al., 2023). Additionally, it is more effective than observer-based surveys in detecting vocal and cryptic species (Hoefer et al., 2023).

In this study, we focus on the Critically Endangered Barton's Robber Frog, *Eleutherodactylus bartonsmithi* Schwartz, 1960, which has an extremely restricted range around the canyon of the Río Yumuri in the Guantánamo Province, southeastern Cuba (Rodríguez, 2012; Rivalta et al., 2014). Individuals of this species have been collected only at its type locality, where advertisement calls of males were also recorded (Alonso Bosch et al., 2007; Díaz and Cádiz, 2007, 2008). Although the species occurs in protected areas, habitat modification appears to be the principal threat to its survival. In October 2016, the area was severely affected by Hurricane Matthew (Stewart, 2017), and following this natural disturbance, human rebuilding caused considerable land movement, and a 4.5-km paved road was constructed modifying the forest.

Eleutherodactylus bartonsmithi was reassessed by the International Union for Conservation of Nature (IUCN) in 2020 (IUCN SSC Amphibian Specialist Group, 2023), and the updated Extent of Occurrence (EOO) of the species included a new locality at 7.5 km from the type locality, in the vicinity of Pozo Azul (A. Rodríguez, pers. comm.). The EOO currently is 21 km^2, but there is no evidence that the species occurs throughout the entire EOO area. According to the IUCN SSC Amphibian Specialist Group (2023) and using a conservative approach, the species is listed as Critically Endangered under criterion B1ab(iii). Herein,

[1] Museo de Historia Natural Felipe Poey, Facultad de Biología, Universidad de la Habana, Calle 25 No. 455 entre J y I, Plaza de la Revolución, 10400 La Habana, Cuba.
[2] EDGE of Existence Programme, Zoological Society of London, Regent's Park, London NW1 4RY, United Kingdom.
[3] Centro Nacional de Biodiversidad, Instituto de Ecología y Sistemática, Carretera Varona No. 11835, Boyeros, 10800 La Habana, Cuba.
[4] Unidad Empresarial de Base Flora y Fauna Baracoa, 1ro Abril No. 18 entre Julio Antonio Mella y Coronel Cardoza, 97310 Baracoa, Guantánamo, Cuba.
[*] Corresponding author. E-mail: mariamcurbelo2061@gmail.com

we provide new records for the species based on a PAM protocol, allowing us to confirm that the population inhabits not only the vicinity of Pozo Azul but other localities outside of its presumed EOO.

Materials and Methods

Study Area. The study area comprises part of two protected areas, the Protected Landscape 'Maisí-Yumurí' and the Outstanding Natural Element 'Cañón de Yumurí', between Maisí and Baracoa Municipalities, Guantánamo Province, southeastern Cuba (Fig. 1). The landscape is composed of plains and plateaus between moderately and weakly modified limestone rocks. At least 15 species of frogs have been recorded in this region (Rivalta et al., 2014), and 12 of them have been listed as threatened on the IUCN Red List.

Calls of *E. bartonsmithi*. Alonso Bosch et al. (2007) provided the first data about the acoustic behaviour of *E. bartonsmithi*, which consisted of calls emitted by an adult male from Boca de Yumurí, Guantánamo Province (Fig. 2A, B). Males of *E. bartonsmithi* vocalise at dusk and dawn from perches on tree trunks, branches, and leaves, at heights of 0.5–3.0 m in the understory; calls are audible to humans from a distance > 20 m (Alonso Bosch et al., 2007). Díaz and Cádiz (2007, 2008) offered the first acoustic characterisation of calls of this species based on calls produced by six individuals from the same locality.

Sampling methodology. The known EOO of 21 km^2 was subdivided into 200 x 200 m parcels, resulting in 105

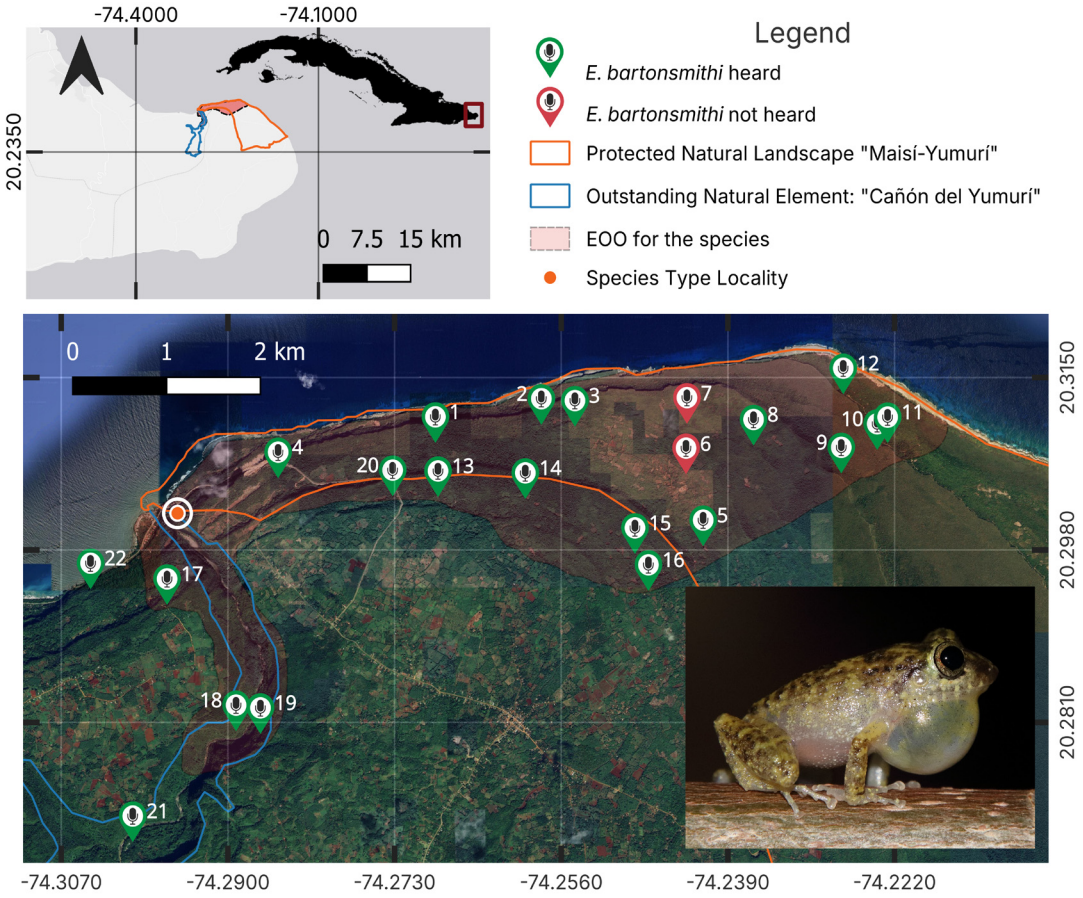

Figure 1. Sites where *Eleutherodactylus bartonmithi* was heard in southeastern Cuba. Several new sites were identified using passive acoustic monitoring. Red markers indicate sites where the species was not heard. The inset at upper left shows the position of the satellite map in eastern Cuba. The bottom right is a male *E. bartonsmithi* vocalising from a tree branch. Photo by Sergio L. del Castillo Domínguez.

parcels. We used a stratified random sampling approach to select 20 parcels within nine zones characterised by abrasive-accumulative marine terraces to conduct passive acoustic monitoring. One AudioMoth remote recording device (Hill et al., 2019) was deployed in each parcel. In August 2024, the devices were set to record continuously for 24 h following a schedule of 58 min on and 2 min off at medium gain and a sampling rate of 48 kHz. In October 2024, the same configuration was used with a modified recording schedule of 10 min on and 5 min off to extend battery life. We placed two additional devices in an area outside the EOO to confirm the species' presence in areas where calls were heard in August. Finally, elevation data for specific geographic coordinates were obtained using the Shuttle Radar Topography Mission (SRTM) dataset, which were processed in QGIS. The Point Sampling Tool was utilised to extract elevation values. At the 20 sites within the EOO, we placed an Elitech RC-51H meteorological sensor to record relative humidity and ambient temperature every 10 min for the entire duration of the sampling period.

Recording analyses. We inspected all recordings made from 04:00–06:00 h after considering the peak calling activity of the species (Curbelo et al., 2025). If no activity was detected during this period, we inspected recordings made from 19:00–20:00 h. Recordings were labelled and examined using Audacity v3.1.3 (Fig. 2C).

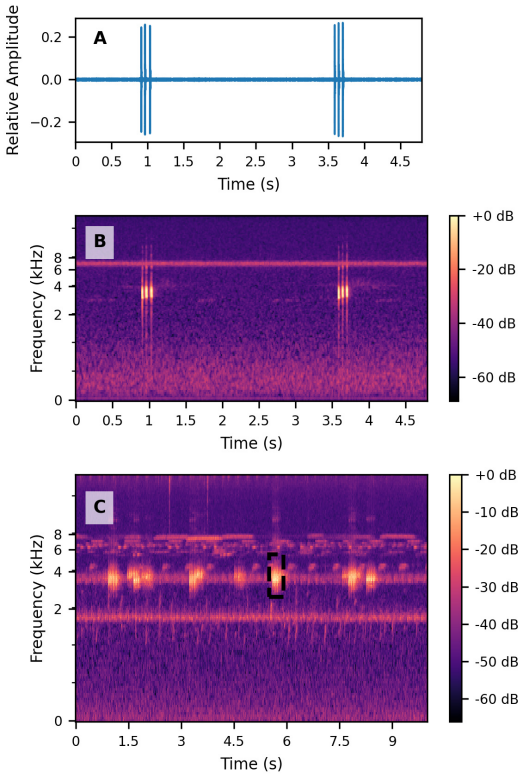

Figure 2. Advertisement calls of *Eleutherodactylus bartonsmithi* from southeastern Cuba. (A) Oscillogram and (B) spectrogram from a sequence of calls of the species from original recordings of Alonso Bosch et al (2007), provided as a reference. (C) Spectrogram of a passive acoustic monitoring recording from Site 5 (Table 1) made at 05:00 h on 9 October 2024. This recording includes overlapping calls of more than one individual of *E. bartonsmithi* (framed in the black-dashed rectangle) but individual calls are clearly visible.

Table 1. Sites (Pt) in Guantánamo Province, southeastern Cuba, where AudioMoth devices were placed to conduct Passive Acoustic Monitoring for *Eleutherodactylus bartonsmithi* in August and October 2024. Coordinates (LAT (°N) -Latitude; LON (°W)- Longitude), elevation (Elv (m)), mean temperature (Temp (°C)), and mean humidity (RH (%)) at the time of detection (05:00–06:00 h) are provided. The species was not detected at Sites 6 and 7. Bullets (•) indicate missing values. The numbering of localities is the same as in Figure 1.

Pt	LAT (°N)	LON (°W)	Elv (m)	Temp (℃)	RH (%)
1	20.3090	74.2688	132	26.9 ± 1.2	80.7 ± 7.7
2	20.3108	74.2580	115	26.8 ± 2.0	87.3 ± 6.3
3	20.3106	74.2546	119	27.1 ± 1.9	81.1 ± 6.3
4	20.3055	74.2849	127	26.7 ± 1.9	89.1 ± 6.3
5	20.2988	74.2415	122	26.8 ± 2.1	86.4 ± 7.1
6	20.3058	74.2433	113	26.8 ± 2.1	86.4 ± 7.4
7	20.3108	74.2432	95	26.9 ± 2.1	86.7 ± 5.7
8	20.3087	74.2364	96	27.0 ± 2.1	85.1 ± 6.6
9	20.3060	74.2274	51	26.1 ± 1.3	91.6 ± 7.9
10	20.3083	74.2238	28	26.5 ± 1.4	89.1 ± 8.5
11	20.30902	74.2227	15	26.1 ± 1.6	89.5 ± 6.6
12	20.3138	74.2272	13	26.0 ± 1.2	92.7 ± 5.9
13	20.3036	74.2686	174	24.8 ± 1.2	95.4 ± 5.0
14	20.3034	74.2597	167	24.9 ± 1.2	94.4 ± 4.5
15	20.29804	74.2485	173	24.8 ± 1.1	94.7 ± 3.6
16	20.2944	74.2471	174	24.8 ± 1.2	95.0 ± 4.6
17	20.2930	74.2962	218	24.6 ± 0.9	94.4 ± 2.0
18	20.2806	74.2892	93	25.0 ± 0.8	97.4 ± 2.1
19	20.2803	74.2867	179	25.1 ± 1.0	96.5 ± 2.6
20	20.3037	74.2732	172	24.9 ± 1.2	94.4 ± 4.8
21	20.2696	74.2997	45	•	•
22	20.2946	74.3040	84	•	•

Results and Discussion

In August 2024 we obtained 775 h of audio recordings, an average of 38.7 h per device, while in October 2024 we recorded 1161 h with an average of 57.9 h per device. *Eleutherodactylus bartonsmithi* was detected in 20 new sites (Fig. 1; Table 1), confirming its presence near Pozo Azul (Site 12) and including two areas that extend the species' EOO (Sites 21 and 22). Given that the advertisement call of *E. bartonsmithi* was comprehensively described by Díaz and Cadiz (2008), we were confident that our automatic recorders could effectively capture them and that we could recognise them. AudioMoth devices have previously been used successfully to monitor arboreal *Eleutherodactylus* species in Puerto Rico (López-Hernández and Puente-Rolón, 2021). This prior knowledge assured us that the data collected would be sufficient to establish a reliable monitoring program, as recommended by Hoefer et al. (2023).

Using PAM proved to be highly effective for detecting the presence of *E. bartonsmithi* males and reducing sampling effort. However, it is important to note that the methodology has certain limitations, particularly its inability to detect females, as they are currently understood to be non-vocal (Ross et al., 2023). Additionally, battery life constrains recording for extended periods (Ross et al., 2023; Teixeira et al., 2024). However, by modifying our recording schedule and switching from alkaline to lithium batteries during October 2024, we extended our recording period to 3 days, enabling a more robust assessment of the species.

The new distributional records have important conservation implications because *E. bartonsmithi* can now be included in the management plan for the Maisí-Yumurí Protected Landscape, where its presence had not been reported before. Two findings stand out in this study: (1) The new records of *E. bartonsmithi* allow for developing ecological niche models to identify other suitable areas where the species might thrive but is currently unknown to occur; and (2) PAM methodology offers a scalable solution for monitoring other critically endangered species that vocalise, including birds and mammals.

Acknowledgments. We thank the Office of Regulation and Environment Safety (ORSA) for providing access permits. We acknowledge the support from the project "Short-term acoustic monitoring of Critically Endangered Cuban amphibian populations: an approach from the soundscape" (2022–2025), of the Sectorial Program "Sustainable use of the components of biological diversity in Cuba of the Ministry of Science, Technology and Environment of the Republic of Cuba" (code No. PS211LH003-02). We thank all the members of the Boca de Yumurí community and park guards of the Outstanding Natural Element "Cañon del Yumurí" and Protected Landscape "Maisí-Yumurí". We also extend our thanks to Neftalí Ríos López for the pre-peer review of our manuscript.

References

Alonso Bosch, R., Rodríguez, A., Márquez, R., Eds. (2007): Sound Guide of the Amphibians from Cuba. Barcelona, Spain, ALOSA.

Alonso Bosch, R., García Padrón, L.Y. (2017): Anfibios. In: Diversidad Biológica de Cuba: Métodos de inventario, monitoreo y colecciones biológicas, p. 348–367. Mancina, C.A., Cruz, D.D., Eds., La Habana, Cuba. Editorial AMA.

Benfer, D.L. (2017): Passive acoustic monitoring of calling activity provides an optimised field survey methodology for the threatened pouched frog, *Assa darlingtoni*. Unpublished M.Sc. thesis, Queensland University of Technology, Brisbane, Queensland, Australia.

Blaustein, A.R., Han, B.A., Relyea, R.A., Johnson, P.T.J., Buck, J.C., Gervasi, S.S., Kats, L.B. (2011): The complexity of amphibian population declines: understanding the role of cofactors in driving amphibian losses. Annals of the New York Academy of Sciences **1223**(1): 108–119.

Curbelo Cruz, M., del Castillo Domínguez, S.L., Galano Machado, L., Herrera Rodeiro, A., Mancina, C.A., Alonso Bosch, R. (2025): A soundscape approach for a short-term acoustic monitoring of a critically endangered Cuban frog. Biodiversity and Conservation **34**(6): 1985–2005.

Desjonquères, C., Gifford, T., Linke, S. (2020): Passive acoustic monitoring as a potential tool to survey animal and ecosystem processes in freshwater environments. Freshwater Biology **65**(1): 7–19.

Diaz, L.M., Cadiz, A. (2007): A descriptive guide for the identification of advertisement calls of cuban frogs of the genus *Eleutherodactylus* (Anura: Leptodactylidae)/Guia descriptiva para la identificacion de las llamadas de anuncio de las ranas cubanas del genero *Eleutherodactylu*s (Anura: Leptodactylidae). Herpetotropicos: Tropical Amphibians & Reptiles **3**(2): 100–123.

Díaz, L.M., Cadiz, A. (2008): Guía taxonómica de los anfibios de Cuba. ABc Taxa **4**: 1–294.

Díaz, L.M., Fong, A., Estrada, A.R., Cádiz, A., González, A., Fernández de Arcila, R., et al. (2023): The amphibians of Cuba: integrative insight into the diversity and conservation of a highly vulnerable fauna. In: The Conservation and Biogeography of Amphibians in the Caribbean, p. 63–175. Ríos-López, N., Heatwole, H., Eds., Exeter, UK, Pelagic Press.

Ford, J., Hunt, D.A.G.A., Haines, G.E., Lewis, M., Lewis, Y., Green, D.M. (2020): Adrift on a sea of troubles: can amphibians survive in a human-dominated World? Herpetologica **76**(2): 251–256.

Hedges, S.B., Cohen, W.B., Timyan, J., Yang, Z. (2018). Haiti's biodiversity threatened by nearly complete loss of primary forest. Proceedings of the National Academy of Sciences USA **115**(46): 11850–11855.

Hill, A.P., Prince, P., Snaddon, J.L., Doncaster, C.P., Rogers, A. (2019): AudioMoth: a low-cost acoustic device for monitoring biodiversity and the environment. HardwareX **6**: e00073.

Hoefer, S., McKnight, D.T., Allen-Ankins, S., Nordberg, E.J., Schwarzkopf, L. (2023): Passive acoustic monitoring in terrestrial vertebrates: a review. Bioacoustics **32**(5): 506–531.

IUCN SSC [International Union for the Conservation of Nature, Species Survival Commission] Amphibian Specialist Group (2023): *Eleutherodactylus bartonsmithi*. The IUCN Red List of Threatened Species **2023**: e.T56452A49732571.

Lodge, D.M. (1993): Biological invasions: lessons for ecology. Trends in Ecology & Evolution **8**(4): 133–137.

López-Hernández, D., Puente-Rolón, A. (2021): The effect of Hurricane María on the richness and calling activity of the *Eleutherodactylus* assemblages of the Carite State Forest, Puerto Rico. Biotropica **53**(6): 1664–1672.

Luedtke, J.A., Chanson, J., Neam, K., Hobin, L., Maciel, A.O., Catenazzi, A., et al. (2023): Ongoing declines for the world's amphibians in the face of emerging threats. Nature **622**(7982): 308–314.

Pabijan, M., Palomar, G., Antunes, B., Antoł, W., Zieliński, P., Babik, W. (2020): Evolutionary principles guiding amphibian conservation. Evolutionary Applications **13**(5): 857–878.

Pitta, E., Kassara, C., Giokas, S., Sfenthourakis, S. (2013): Compositional dissimilarity patterns of reptiles and amphibians in insular systems around the world. Ecological Research **28**(4): 633–642.

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.

Rivalta, V., Schettino, L.R., Mancina, C.A., Iturriaga, M. (2014): Amphibians of Cuba: checklist and geographic distributions. Smithsonian Herpetological Information Service **145**: 1–48.

Rodríguez, A. (2012): *Eleutherodactylus bartonsmithi*. In: Libro rojo de los vertebrados de Cuba, p. 63–64. González Alonso, H., Rodríguez Schettino, L., Rodríguez, A., Mancina., C.A., Ramos Garcia, I., Eds., La Habana, Cuba, Editorial Academia.

Ross, S. R. P. -J., O'Connell, D. P., Deichmann, J. L., Desjonquères, C., Gasc, A., Phillips, J. N., Sethi, S. S., Wood, C. M., & Burivalova, Z. (2023): Passive acoustic monitoring provides a fresh perspective on fundamental ecological questions. Functional Ecology **37**(4): 959–975.

Stewart, S.R. (2017): National Hurricane Center Tropical Cyclone Report: Hurricane Matthew (AL142016), NOAA Technical Report.

Teixeira, D., Maron, M., Van Rensburg, B.J. (2019): Bioacoustic monitoring of animal vocal behavior for conservation. Conservation Science and Practice **1**(8): e72.

Teixeira, D., Roe, P., Rensburg, B., Linke, S., McDonald, P., Tucker, D., Fuller, S. (2024): Effective ecological monitoring using passive acoustic sensors: Recommendations for conservation practitioners. Conservation Science and Practice **6**(6): e13132.

Accepted by Anyelet Valencia-Aguilar