Distress call of *Boana geographica* (Spix, 1824) recorded in the state of Maranhão, Brazil

João Lucas Pereira Ferreira[1,2*], Kássio de Castro Araújo[2], Lucas Rafael Uchôa[1,2], Caio Vinícius de Mira-Mendes[3], Etielle Barroso de Andrade[2]

1 Programa de Pós-Graduação em Zoologia, Departamento de Ciências Biológicas, Universidade Estadual de Santa Cruz-UESC, Rodovia Jorge Amado, km 16, 45662-900 Ilhéus, BA, Brazil

2 Grupo de Pesquisa em Biodiversidade e Biotecnologia do Centro-Norte Piauiense-BIOTECPI, Instituto Federal de Educação, Ciência e Tecnologia do Piauí-IFPI Campus Pedro II, Rua Antonino Martins de Andrade 750, Engenho Novo, Pedro II, 64255-000 Piauí, Brazil

3 Departmento de Biologia, Universidade Estadual do Maranhão, 65055-310 São Luís, MA, Brazil

Corresponding author. Email: *jooaolukas247@gmail.com*

DOI: *10.5281/zenodo.14291738*

Anuran vocalization can vary in different social contexts, including reproductive, aggressive, and defensive calls (Toledo and Haddad, 2009; Toledo et al., 2014). Among the defensive calls, three subcategories can be identified: alarm, warning, and distress calls (Toledo et al., 2014; Ferreira et al., 2019). This later is usually emitted with the mouth open and during subjugation by a potential predator (Toledo et al., 2005; Toledo et al., 2014; Ferreira et al., 2019). Although distress calls are known from almost 100 species in 38 genera, they are commonly observed in *Boana* and *Leptodactylus* species (Ferreira et al., 2019).

Boana geographica (Spix, 1824) belongs to the *B. semilineata* group (Faivovich et al., 2005) and is a treefrog with nocturnal foraging habits whose reproductive period extends throughout the year (Anjos et al., 2021). It is distributed from northern Bolivia and adjacent southeastern Peru to western Brazil (Frost, 2024). The known vocal repertory of *B. geographica* is restricted to its advertisement call (Fouquet et al., 2016). In this work, we describe the distress call of *B. geographica* recorded in the state of Maranhão, northeastern Brazil, and compare it to other species of *Boana*.

During fieldwork carried out on April 20, 2023 at Reserva Particular do Patrimônio Natural (RPPN) Mansinha (7°8'5.02"S; 47°26'5.13"W, datum WGS84), municipality of Carolina, near Chapada das Mesas National Park, state of Maranhão, northeastern Brazil, we collected an adult male *Boana geographica* (Fig. 1) on the banks of a small stream in the middle of a gallery forest. The individual was found on a tree trunk around 10h00 a.m., collected manually, and transported in a plastic bag to the support base. The animal emitted a distress call when removed from the plastic bag with immobilized legs.

We recorded the distress call using a smartphone with a sampling rate of 44.1 kHz and resolution of 32 bits. We analyzed the calls in the Raven Pro v.1.6.1 (Bioacoustics Research Program, 2019) software using the settings: window type = Hanning, window size = 512 samples; 3 dB filter bandwidth = 124 Hz; overlap = 95% (locked), hop size = 0.59 ms, DFT size = 512 samples, grid spacing = 86.1 Hz; brightness = 60%; contrast = 54%. We analyzed the following acoustic parameters: call duration, inter-call interval (s), minimum frequency (Hz), maximum frequency (Hz), dominant frequency (Hz), and bandwidth 90% (Hz) (Köhler et al., 2017). The minimum and maximum frequencies were obtained through "Frequency 5%" and "Frequency 95%" functions in Raven Pro v.1.6.1 (Bioacoustics Research Program, 2019). Note and call terminologies follow Köhler et al. (2017) using a note-centered approach. Sound figure was produced using the packages Seewave v.2.1.6 (Sueur et al., 2008) and tuneR v.1.3.3 (Ligges et al., 2017), in R v.4.0.4 (R Core Team 2021), with the following settings: window = Hanning; FFT size = 512 samples; FFT overlap = 70%; color scale = 60 dB relative. Following the recording process, the specimen was euthanized following approved procedures, fixed in 10% formalin, and preserved in 70% alcohol. The specimen was deposited in the Coleção Biológica da Universidade Estadual do Maranhão – UEMA *Campus* Paulo VI, São Luís, Maranhão, Brazil (CFMAN107). The video and audio were deposited at Fonoteca Neotropical Jacques Vielliard (FNJV 77623).

The distress call description was based on a 60 s recording containing 12 calls. The distress call consists of a pulsatile and harmonically complex structure with mean 43.83 harmonics [Standard Deviation (SD) 3.88 harmonics; 38–50 harmonics], emitted with the mouth open. The call duration was 0.635 s (SD 0.183 s; 0.413–0.977 s), inter-call interval of 4.143 s (SD 4.824 s; 0.322–16.588 s), minimum frequency (5%) of 1945 Hz (SD 518 Hz; 1291–2756 Hz), maximum frequency (95%) of 7428 Hz (SD 3626 Hz; 3617–16106 Hz), and dominant frequency of 2985 Hz (SD 221 Hz; 2583–3273 Hz). However, *B. geographica*

showed variation in the distress call, emitting longer single notes followed by two or three shorter notes grouped together (Fig. 2a). Analyzed separately, the longest notes (n = 3) had an average duration of 0.903 s (SD 0.084 s; 0.812–0.977 s), minimum frequency (5%) of 2325 Hz (SD 479 Hz; 1808–2756 Hz), maximum frequency (95%) of 5713 Hz (SD 1819 Hz; 3617–6890 Hz) and dominant frequency of 3043 Hz (SD 49 Hz; 3014–3100 Hz). These exhibited abrupt ascending frequency modulation at the beginning and descending at the end of the call, with a frequency bandwidth of 3387 Hz (SD 1920 Hz; 1205–4823 Hz), mainly included between the 5th and 8th harmonics (Fig. 2b). The shorter notes (n = 3) had an average duration of 0.546 s (SD 0.093 s; 0.413–0.687 s), minimum frequency (5%) of 1818 Hz (SD 489 Hz; 1291–2411 Hz), maximum frequency (95%) of 8000 Hz (SD 3972 Hz; 3789–16106 Hz), and dominant frequency of 2966 Hz (SD 255 Hz; 2583–3273 Hz). The short notes also exhibited abrupt ascending frequency modulation at the beginning and descending at the end of the call, showing greater energy distribution along the harmonics with a frequency bandwidth of 6182 Hz (SD 4078 Hz; 2497–14642 Hz; Fig. 2c).

Distress calls have been reported from 108 anuran species worldwide, of which 37% are from the Hylidae, with most of these from *Boana* (42 distress calls described; Forti et al., 2018; 2020). The distress call of *B. geographica* has the same characteristics (pulsatile and harmonically structure) as described for other species of the Hylidae (e.g., Toledo and Haddad, 2009; Guerra et al., 2017; Forti et al., 2020). Within the *B. semilineata* group, only *B. boans* has its distress calls described (Hödl and Gollman, 1986). Although Toledo and Haddad (2009) tested several individuals of *B. pombali* and *B. semilineata* for the emission of distress call, both species showed no response. The duration and dominant frequency of the *B. boans* distress call (0.427–1.350 s; 3000–4000 Hz; Höld and Gollman, 1986) is similar to the longer notes of *B. geographica* (mean 3043 Hz; SD 49 Hz; 3014–3100 Hz), except for the abruptly increasing and decreasing frequency modulation at the beginning and end, respectively, in *B. geographica*. Furthermore, the authors reported that no clear harmonic structures were observed in distress call of *B. boans* (Hödl and Gollman, 1986).

Although smartphones record acoustic signals differently from professional equipment, their use has increased in recent years (Roh et al., 2014; Modak et al., 2016; Weaver et al., 2020; Fernandes et al., 2023). Smartphones and cameras with built-in microphones are not recommended for recording frog calls, but their use is advocated in unexpected cases when professional equipment is unavailable (Köhler et al., 2017). Smartphones have different de-

tection ranges and frequency responses (Zilli, 2015), however, the quality of the built-in microphones impacts the temporal parameters of recorded calls more strongly than the dominant frequency (Kardous and Shaw, 2014; Köhler et al., 2017).

In this case, because there may be bioacoustic differences resulting from the equipment used (Köhler et al., 2017) or the degree of stress of the anurans (handled and preyed upon; Costa et al., 2022), we present temporal parameters of the different types of notes emitted but draw attention to the structural aspects and behavioral characteristics during the issuance of the distress call of *B. geographica*. This was an event recorded opportunistically during a study of this rare species. Toledo and Haddad (2009) attempted to induce distress calls from *B. geographica* but were unsuccessful. In this study, *Boana geographica* emitted a distress call when handled. Our results provide relevant data on acoustic communication in treefrogs and contribute to the understanding of bioacoustic parameters in the *B. semilineata* group.

ACKNOWLEDGMENTS

We thank the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) for the collecting permits (SISBIO, 82619/1). J.L.P.F. thanks the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), K.C.A. thanks the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Fundação de Amparo à Pesquisa do Estado do Piauí (FAPEPI) for providing research fellowship (Process: 150013/2023-0), L.R.U. thanks the Fundação de Amparo à Pesquisa do Estado da Bahia (FAPESB) for the fellowship (Nº BO0450/2022), C.V.M.M. thanks the Fundação de Amparo à Pesquisa do Estado do Maranhão (FAPEMA) for the financial support (Process Universal – 06703/22) and Universidade Estadual do Maranhão (UEMA; sênior productivity grant 05/2023-PPG/UEMA).

REFERENCES

Anjos C.S., Souza F.C., Costa G.N., Malta J.C.O., Zuanon J.A.S. 2021. Tadpoles of *Boana geographica* (Spix, 1824) (Anura: Hylidae) parasitized by *Argulus* sp. (Branchiura: Argulidae) in a Central Amazonia Forest stream. *Herpetology Notes* 14:335–339.

Bioacoustics Research Program. 2019. Raven Pro: interactive Sound Analysis Software, Version 1.6.1. Accessible at: *http://www.birds.cornell.edu/raven*. Accessed: 09 January 2024.

Costa C.A., Uchôa L.R., Araújo S.C.M., Oliveira M.S., Andrade E.B. 2022. Predator-prey: predation strategies of *Leptodactylus macrosternum* and de-

fensive behavior of *Leptodactylus fuscus*. *Acta Brasiliensis* 6:61–64. *https://doi.org/10.22571/2526-4338586*

Faivovich J., Haddad C.F., Garcia P.C., Frost D.R., Campbell J.A., Wheeler W.C. 2005. Systematic review of the frog family Hylidae, with special reference to Hylinae: phylogenetic analysis and taxonomic revision. *Bulletin of the American Museum of natural History* 2005:1–240. *https://doi.org/10.1206/0003-0090(2005)294[0001: SROTFF]2.0.CO:2*

Fernandes I.Y., Koch E.D., Monico A.T. 2023. First record of a snake call in South America: the unusual sound of an ornate snail-eater *Dipsas catesbyi*. *Acta Amazonica* 53:243–245. *https://doi.org/10.1590/1809-4392202300431*

Ferreira R.B., Lourenço-de-Moraes R., Zocca C., Duca C., Beard K.H., Brodie E.D. 2019. Antipredator mechanisms of post-metamorphic anurans: a global database and classification system. *Behavioral Ecology and Sociobiology* 73:1–21. *https://doi.org/10.1007/s00265-019-2680-1*

Forti L.R., Costa-Campos C.E. 2020. Distress calls of two Amazonian species of *Boana* (Anura, Hylidae). *Herpetology Notes* 13:855–858.

Forti L.R., Zornosa-Torres C., Márquez R., Toledo L.F. 2018. Ancestral state, phylogenetic signal and convergence among anuran distress calls. *Zoologischer Anzeiger* 274:1–5. *https://doi.org/10.1016/j.jcz.2018.02.004*

Fouquet A., Martinez Q., Zeidler L., Courtois E.A., Gaucher P., Blanc M., ... Kok P.J. 2016. Cryptic diversity in the *Hypsiboas semilineatus* species group (Amphibia, Anura) with the description of a new species from the eastern Guiana Shield. *Zootaxa* 4084:79–104. *https://doi.org/10.11646/zootaxa.4084.1.3*

Frost D.R. 2024. Amphibia Species of the World: an online reference. Version 5.0. Accessible at: *http://research.amnh.org/herpetology/amphibia/*. Accessed: 16 July 2024

Guerra V., Lingnau R., Bastos R.P. 2017. Vocalizations and bioacoustic analysis of *Boana jaguariaivensis* (Caramaschi, Cruz, and Segalla, 2010) (Anura: Hylidae). *South American Journal of Herpetology* 12:34–41. *https://doi.org/10.2994/SAJH-D-16-00018.1*

Hödl W., Gollmann G. 1986. Distress class in neotropical frogs. *Amphibia-Reptilia* 7:11–21.

Kardous C.A., Shaw P.B. 2014. Evaluation of smartphone sound measurement applications. *The Journal of the Acous-*

tical Society of America 135:186–192. *https://doi.org/10.1121/1.4865269*

Köhler J., Jansen M., Rodriguez A., Kok P.J., Toledo L.F., Emmrich M., ... Vences M. 2017. The use of bioacoustics in anuran taxonomy: theory, terminology, methods and recommendations for best practice. *Zootaxa* 4251:1–124. *https://doi.org/10.11646/zootaxa.4251.1.1*

Ligges U., Krey S., Mersmann O., Schnackenberg S. 2017. TuneR: analysis of music and speech. Accessible at: *https://CRAN.Rproject.org/package=tuneR/*. Accessed: 10 May 2024.

Modak N., Dahanukar N., Ogale H., Padhye A. 2016. Advertisement calls of Amboli leaping frog *Indirana chiravasi* (Anura: Ranixalidae) from northern Western Ghats, India. *Current Science* 110:2220–2223.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, Version 4.0.4. Accessible at: *https://www.R-project.org/*. Accessed: 10 May 2024.

Roh G., Borzée A., Jang Y. 2014. Spatiotemporal distributions and habitat characteristics of the endangered treefrog, *Hyla suweonensis*, in relation to sympatric *H. japonica*. *Ecological Informatics* 24:78–84. *https://doi.org/10.1016/j.ecoinf.2014.07.009*

Sueur J., Aubin T., Simonis C. 2008. Seewave, a free modular tool for sound analysis and synthesis. *Bioacoustics* 18:213–226. *https://doi.org/10.1080/09524622.2008.9753600*

Toledo L.F., Haddad C.F.B. 2009. Defensive vocalizations of Neotropical anurans. *South American Journal of Herpetology* 4:25–42. *https://doi.org/10.2994/057.004.0104*

Toledo L.F., Martins I.A., Bruschi D.P., Passos M.A., Alexandre C., Haddad C.F. 2014. The anuran calling repertoire in the light of social context. *Acta ethologica* 18:87–99. *https://doi.org/10.1007/s10211-014-0194-4*

Toledo L.F., Tozetti A., Zina, J. 2005. *Leptodactylus labyrinthicus* (Pepper Frog): defensive repertoire. *Herpetological Bulletin* 90:29–31.

Weaver S.J., Callaghan C.T., Rowley J.J. 2020. Anuran accents: Continental-scale citizen science data reveal spatial and temporal patterns of call variability. *Ecology and Evolution* 10:12115–12128. *https://doi.org/10.1002/ece3.6833*

Zilli D. 2015. Smartphone-powered citizen science for bioacoustic moni-toring. Ph.D. Dissertation, University of Southampton, England.

Ariadne F. Sabbag

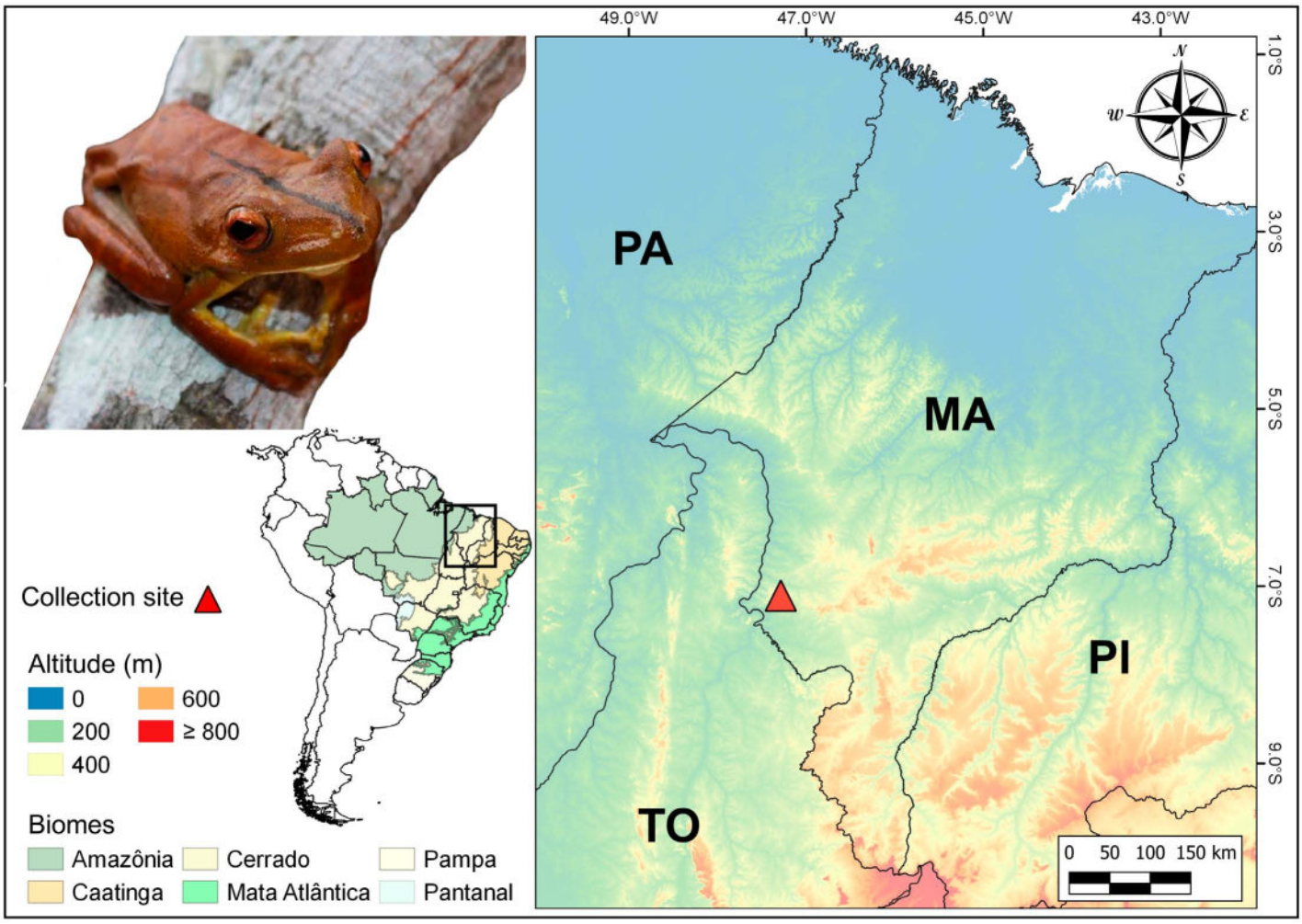

Figure 1. Location of *Boana geographica* recorded in the Reserva Particular do Patrimônio Natural (RPPN) Mansinha, municipality of Carolina, state of Maranhão, Northeastern Brazil.

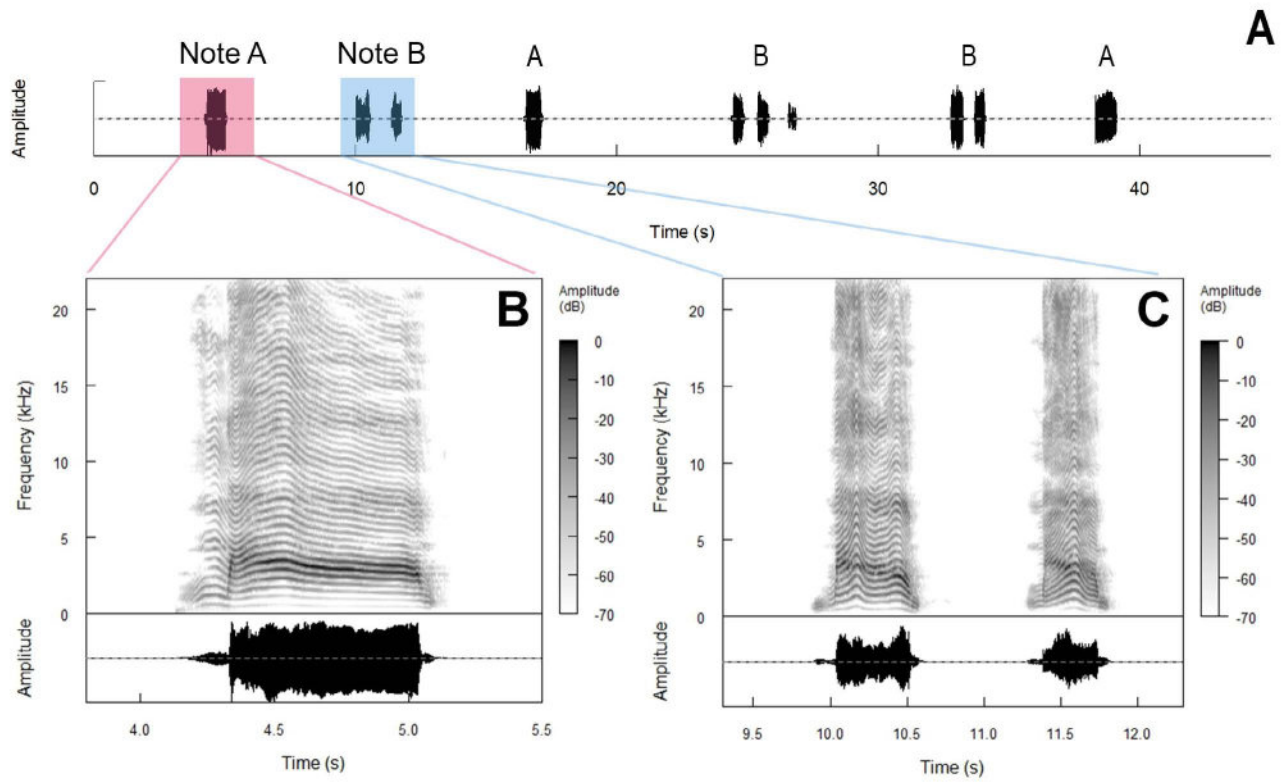

Figure 2. *Boana geographica* distress call recorded in the Reserva Particular do Patrimônio Natural (RPPN) Mansinha, municipality of Carolina, state of Maranhão, Northeastern Brazil. **A** – Oscillogram showing the complete distress call; **B** and **C** – Detail of the oscillogram and spectrogram of notes **A** and **B**, respectively.