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Frog diversity of Santana Island, Amapá State, northern Brazil

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Abstract. We here provide information on the species composition of frogs for Santana Island, Amapá State, northern Brazil. A series of visual active searches allowed us to record 24 species from five families, including Hylidae (15 species), Leptodactylidae (4), Bufonidae (3), Microhylidae (1), and Pipidae (1). Four of these, *Boana lanciformis*, *Dendropsophus haraldschultzi*, *Scinax garbei*, and *Elachistocleis helianneae*, are new records for Amapá State. Almost all frogs occurring on Santana Island were classified as Least Concern based on Red List criteria, with only two species (*Rhinella major*, *Lysapsus bolivianus*) classified as Data Deficient. The species accumulation curve showed a strong tendency toward stabilization but indicated that some additional sampling is needed to record all species. In addition, the correlation between climatic conditions and species richness was only significant for rainfall. Our results increase the knowledge of the frog fauna in the eastern Amazon and provide needed information for conservation activities in the region.

Key words. Amphibians, conservation, eastern Amazon, *Boana lanciformis*, *Dendropsophus haraldschultzi*, *Scinax garbei*, *Elachistocleis helianneae*, new records

Introduction

The amphibian fauna of Brazil comprises 1188 species (Segalla et al., 2021). By far the highest diversity exists among the frogs (1144 species, including two exotics), which are represented by 20 families and 107 genera, followed by caecilians with 39 species (four families, 13 genera), and five salamanders (one family and genus). Despite conservation efforts, deforestation throughout Brazil has caused amphibian population declines and even some extinctions, and deforestation is considered the greatest threat to the country's biodiversity (e.g., Young et al., 2001; Eterovick et al., 2005; Fearnside, 2005; Campos et al., 2014).

In this context, a better understanding of the local diversity of anurans can contribute to preventing amphibian population declines, an effort that has been hampered by a lack of information and implementation of effective government policies (Eterovick et al., 2005; Campos et al., 2014). Thus, amphibian inventories are of great relevance so that region-specific strategies for conservation can be defined (Nogueira et al., 2009). Such studies have often led to the description of new species, and they contribute significantly to the knowledge of this critical natural resource (e.g., Ávila-Pires et al., 2007).

In the Brazilian Amazon, amphibian inventories are still relatively scarce, due to the difficulty with access to many areas (Azevedo-Ramos and Galatti, 2002; Funk et al., 2012). For this reason, most studies have been restricted to the states of Amazonas (Prudente et al., 2013; Waldez et al., 2013; Ramalho et al., 2016; Menin et al., 2017; Simões et al., 2019), Pará (Mendes-Pinto and Souza, 2011; Bernardo et al., 2012; Vaz-Silva et al., 2015, Ávila-Pires et al., 2018), Rondônia (Bernarde, 2007; Piatti et al., 2012), and Acre (Bernarde et al., 2011; Bernarde et al., 2013; Miranda et al., 2015; Venâncio and Souza, 2016; Fonseca et al., 2019; Freitas et al., 2020).

Amapá State, located in eastern Amazonia, has high biodiversity but there are relatively few studies of the frog fauna (Queiroz et al., 2011; Pereira-Júnior et al., 2013; Araújo and Costa-Campos, 2014; Benício and Lima, 2017; Lima et al., 2017; Silva e Silva and Costa-Campos, 2018; Costa-Campos and Freire, 2019; Pedroso-Santos et al., 2019). However, these studies allowed an assessment of the species distribution of frogs in the state (Costa-Campos et al., 2014; Silva e Silva and Costa-Campos, 2014; Corrêa et al., 2015; Costa-Campos and Freire, 2015; Costa-Campos et al., 2016; Silva e Silva and Costa-Campos, 2016; Missassi et al., 2017; Lima et

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al., 2019; Costa-Campos et al., 2020a, b, c; Figueiredo et al., 2020; Costa-Campos et al., 2021; Dias-Souza et al., 2021; Figueiredo et al., 2021).

Santana Island is part of the geomorphological unit known as the Plain of Estuaries and Deltas of Amapá, and it receives fluvial influence from the Amazon River with some areas subject to periodic flooding from rainwater and river water levels (Valente et al., 1998). With a high level of landscape and human disturbance, only studies of vegetation (Freitas et al., 2010), host plants and parasitoids (Silva et al., 2007; Saraiva et al., 2019), and use of soil and climate (EMBRAPA, 1996; Freitas, 2008; Vilhena, 2017) have been completed on the island. In this context, the present study provides the first listing of frogs, including richness and constancy of occurrence of species, for Santana Island, Santana Municipality, Amapá State, eastern Amazon, Brazil.

Materials and Methods

Study area. Fieldwork was conducted on the banks of the North Channel, Santana Island Santana Municipality, Amapá State, northern Brazil (0.0795°S, 51.1743°W). This is an island of approximately 20.05 km^2 area, with a predominance of savanna, *terra firme* "upland" forest, and *várzea* forest (Valente et al., 1998).

Sampling. We employed two sampling strategies during the months of October 2012–August 2013, visual encounter survey and auditory recording (Crump and Scott, 1994; Heyer et al., 1994; Zimmerman, 1994). Three collection points were determined, one in flooded forest (FF), another at a permanent pond (PP), and the third in upland forest (UF), where the collections were performed at night (18:00 h to midnight). All specimens were euthanized with 5% lidocaine, fixed in 10% formalin, preserved in 70% ethanol, and deposited in the herpetological collection of Universidade Federal do Amapá. Species conservation status was obtained from the *Red List of Threatened Species* (IUCN, 2020) and the *Brazil Red Book of Threatened Species of Fauna* (ICMBio, 2018).

Data analysis. To analyse the relative abundance of anurans, we built a Whittaker plot obtained by ranking species starting with the most abundant along the Y-axis and with the logarithm of abundances on the X-axis (Magurran, 2011). Each recorded species was classified according to the constancy of occurrence index (Dajoz, 1983), which allowed its presence to be considered constant (present in > 50% of samples), accessory (present in 25–50% of samples), or accidental (present in < 25% of samples).

To evaluate sampling effort, we constructed an accumulation species curve. Species richness of the sampled area was estimated by extrapolation of a species accumulation curve using Jackknife 1 and Bootstrap estimators with 1000 randomizations in the software EstimateS v.9.1.0 (Colwell, 2013). We conducted the richness comparisons using the Jaccard similarity index and the unweighted pair-group method with averaging (UPGMA) (Magurran, 2011). The cophenetic correlation coefficient was calculated to indicate the degree of representability of the similarity matrix in the dendrogram, allowing for the identification of groups formed by the evaluated localities, considering the similarities they presented in relation to species richness. The cluster analysis was performed on the software Past 3.06 (Hammer et al., 2001).

The Spearman Correlation Coefficient was applicated to compare climatic conditions (available from the NHMET database) during studies with species richness. Statistical analyses were performed with BIOESTAT 5.3 software (Ayres et al., 2007), using a significance index of $p < 0.05$ for all analyses.

Results

We recorded 24 species of anurans from five families (Figs. 1–4; Table 1). The family with most representatives was Hylidae (15 species), followed by Leptodactylidae (4), Bufonidae (3), Microhylidae (1), and Pipidae (1). Three species (*Rhinella major*, *R. marina*, *Scinax ruber*) were found in all sampled areas. According to the *IUCN Red List of Threatened Species* (IUCN, 2020), 91.6% ($n = 22$) of the species that occur on Santana Island are classified as Least Concern. Only two species (*Rhinella major*, *Lysapsus bolivianus*) are classified as Data Deficient.

Lysapsus bolivianus, *Adenomera hylaedactyla*, and *Leptodactylus fuscus* were the most abundant species, together representing 38.9% of all specimens collected, followed by *Rhinella major* (7.5%) and *Scinax ruber* (7%). According to the constancy of occurrence index, the presence of eight species was constant, eight were accessory, and eight should be considered accidental (Fig. 5; Table 1). The species accumulation curve showed that the sampling effort was not enough to record all species but showed a strong tendency toward stabilization (Fig. 6).

The cluster analysis revealed three distinct groups, one comprising the upland forest and flooded forest, which were similar in their composition of anurans, and the other, consisting of the permanent pond (Fig. 7). We

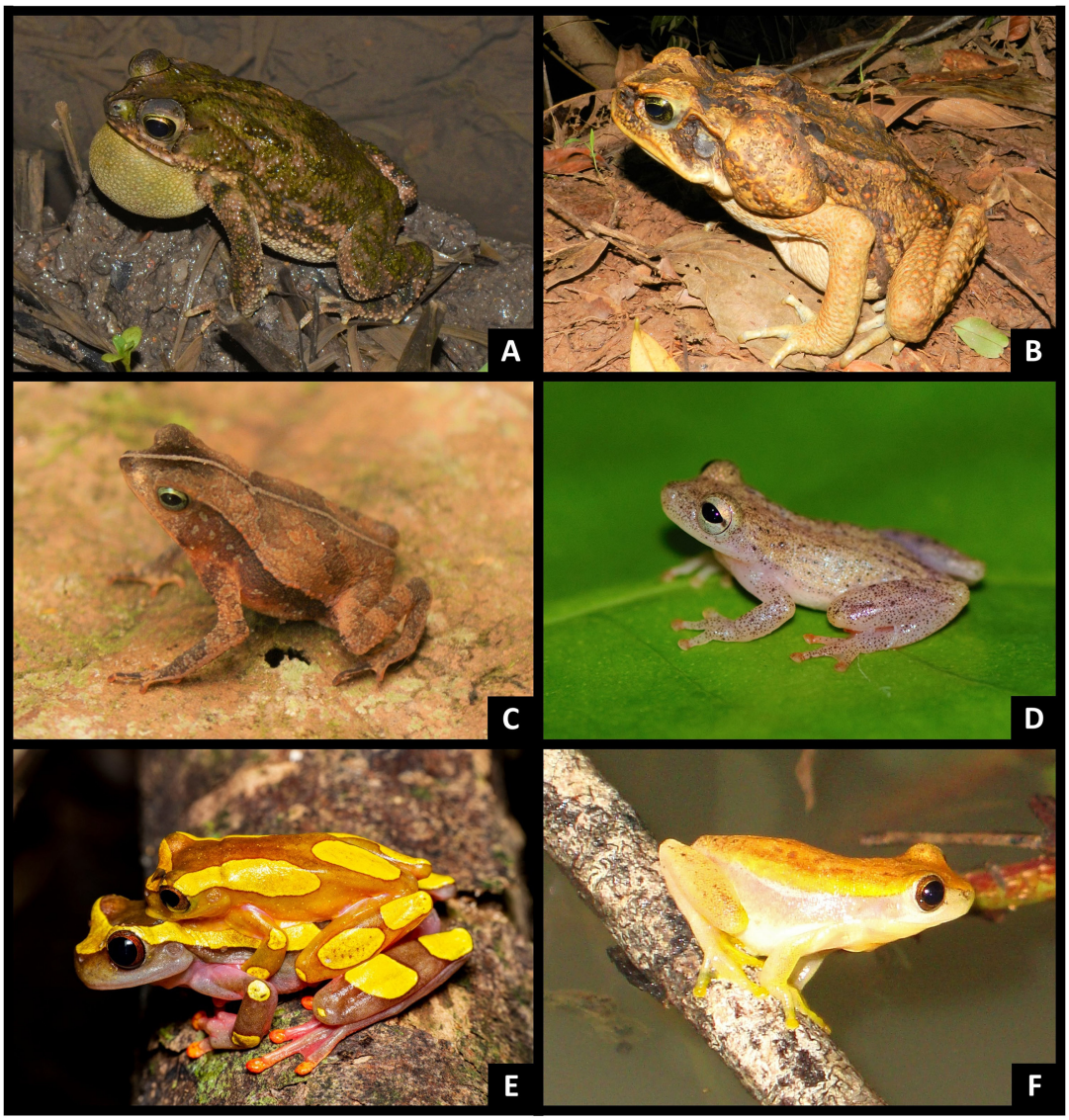

Figure 1. Selected anuran species recorded on Santana Island, Amapá State, northeastern Brazil. (A) *Rhinella major*. (B) *R. marina*. (C) *R.* gr. *margaritifera*. (D) *Dendropsophus haraldschultzi*. (E) *D. leucophyllatus*. (F) *D. walfordi*. Photos by Carlos E. Costa-Campos (A–D, F) and Wirley Almeida-Santos (E).

verified that each of these groups contains a different set of species.

The Spearman Coefficient Correlation values for species richness were not significant for temperature (ρ = –0.4518, p = 0.1629) and relative air humidity (ρ = 0.5263, p = 0.096), but there was a significant difference for rainfall (ρ = 0.7277, p = 0.0111).

Discussion

The frog assemblage recorded on Santana Island represent a subset of the species diversity seen at other localities in Amapá State. It includes about 33.3% of the species found in the Reserva Biológica do Parazinho (Araújo and Costa-Campos, 2014), 35.5% of species in the Área de Proteção Ambiental do Rio Curiaú (Lima et al., 2017), 17.5% of species in the Reserva Extrativista do Rio Cajari (Queiroz et al., 2011), 26.5% of species

Figure 2. Additional anuran species from Santana Island, Amapá State, northeastern Brazil. (A) *Boana boans*. (B) *B. lanciformis*. (C) *B. punctata*. (D) *Osteocephalus taurinus*. (E) *Lysapsus bolivianus*. (F) *Pseudis paradoxa.* Photos by Carlos E. Costa-Campos.

in the Parque Natural Municipal do Cancão (Silva e Silva and Costa-Campos, 2018), 16% of species in the Reserva Extrativista Municipal Beija-Flor Brilho de Fogo (Pedroso-Santos et al., 2019), and 57.1% of the species in the savanna areas of Amapá State (Costa-Campos and Freire, 2019). The lower diversity of anurans found in our study may be related to the close association of the island with the adjacent urban matrix, a factor that has been observed to reduce the diversity of frog species in other areas of Amapá State (Pereira-Júnior et al., 2013; Pedroso-Santos et al., 2019) and in the Brazilian Amazon (Knispel and Barros, 2009; Menin et al., 2019).

The greatest frog diversity on Santana Island was found among hylid and leptodactylid species, a similar scenario as found in other studies of neotropical frogs (e.g., Ávila-Pires et al., 2010; Menin et al., 2017). *Boana lanciformis*, *Dendropsophus haraldschultzi*, *Scinax garbei*, and *Elachistocleis helianneae* are new records for this island, which demonstrates that continued sampling of frogs in the region is needed to provide a better understanding of

Figure 3. More anuran species found on Santana Island, Amapá State, northeastern Brazil. (A) *Scinax boesemani*. (B) *S. garbei*. (C) *S. nebulosus*. (D) *S. ruber*. (E) *Sphaenorhynchus lacteus*. (F) *Trachycephalus typhonius*. Photos by Carlos E. Costa-Campos.

biodiversity (Costa-Campos et al., 2014; Silva e Silva and Costa-Campos, 2014; Costa-Campos and Freire, 2015; Missassi et al., 2017). *Rhinella* gr. *margaritifera* presents uncertainties in terms of unresolved taxonomic issues, which indicates the need for additional taxonomic work on the local fauna.

Despite the rarefaction curve showing a tendency toward stabilization, future and complementary studies using different collection methods and increased sampling time during fieldwork are necessary, to finalize the count of species diversity in the studied area. In fact, there are environments on Santana Island that have not yet been surveyed (e.g., open areas) and which may shelter frog species not yet recorded. The dominance of a few species over the others is demonstrated by the inverted "J" distribution in the Whittaker plot. According to Magurran (2011), most biological assemblages follow this pattern, and this can be explained by the central limit theory, which states that if a large number of independent factors, such as rainfall, acts on a certain variable (e.g. richness, abundance), it tends to acquire a normal distribution.

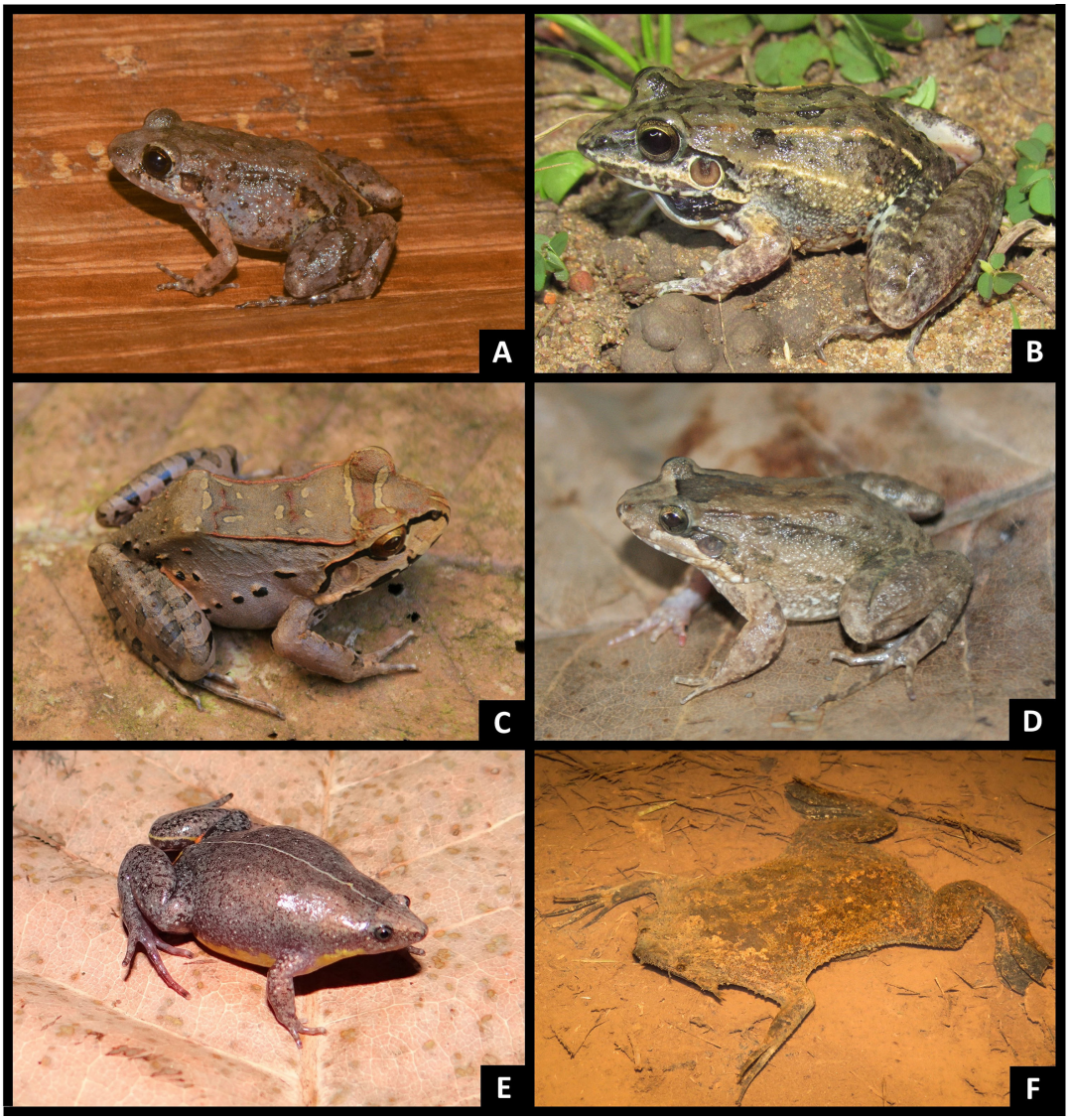

Figure 4. Another set of anuran species record on Santana Island, Amapá State, northeastern Brazil. (A) *Adenomera hylaedactyla*. (B) *Leptodactylus fuscus*. (C) *L. pentadactylus*. (D) *L. podicipinus*. (E) *Elachistocleis helianneae*. (F) *Pipa pipa*. Photos by Carlos E. Costa-Campos.

The cluster analysis of the anuran assemblages generated revealed three distinct groups. Groups 1 and 2 reveal a more distinct assemblage. Group 3 is located on the right bank of the Amazon River, which generally has high values of abundance and richness. Our results corroborate the river hypothesis, in which rivers may play a major role in creating barriers separating populations and allowing their differentiation (Haffer, 2008; Vaz-Silva et al., 2015; Pirani et al., 2019).

The positive correlation between species richness and rainfall corroborates the idea that anuran breeding activity is closely related to the rainy season (Canelas and Bertoluci, 2007; Kopp et al., 2010; Vasconcelos et al., 2010; Dias et al., 2014; Silva e Silva and Costa-Campos, 2018). Results such as these are important in supporting conservation action in the region. In addition, this list of species increases our knowledge of the frog fauna in the eastern Amazon.

Table 1. List of anuran species recorded on Santana Island, Amapá State, Brazil. Abbreviated column headings include the total number of collected specimens (*n*), sample areas (flooded forest – FF, permanent pond – PP, upland forest – UF), the sampling technique (active visual search – AVS, auditory search – AS), and the constancy of occurrence (constant – CON, accessory – ACE, Accidental – ACC).

Family/Species	*n*	Sample Area			Sampling		Constancy		
		FF	PP	UF	AVS	AS	CON	ACE	ACC
Bufonidae									
Rhinella gr. *margaritifera* (Laurenti, 1768)	4			x	x			x	
Rhinella marina (Linnaeus, 1758)	8	x	x	x	x	x	x		
Rhinella major (Spix, 1824)	16	x	x	x	x		x		
Hylidae									
Boana boans (Linnaeus, 1758)	1			x	x				x
Boana lanciformis (Cope, 1871)	8	x	x		x	x		x	
Boana punctata (Schneider, 1799)	12	x	x		x	x		x	
Dendropsophus haraldschultzi (Bokermann, 1962)	7	x			x	x	x		
Dendropsophus leucophyllatus (Beireis, 1783)	5	x			x				x
Dendropsophus walfordi (Bokermann, 1962)	10	x	x		x			x	
Lysapsus bolivianus (Gallardo, 1961)	32	x	x		x	x	x		
Osteocephalus taurinus (Steindachner, 1862)	6		x	x	x	x		x	
Pseudis paradoxa (Linnaeus, 1758)	4	x	x		x	x			x
Scinax boesemani (Goin, 1966)	14		x		x				x
Scinax garbei (Miranda-Ribeiro, 1926)	5	x	x		x				x
Scinax nebulosus (Spix, 1824)	2	x	x		x	x			x
Scinax ruber (Laurenti, 1768)	15	x	x	x	x			x	
Sphaenorhynchus lacteus (Daudin, 1800)	1	x			x				x
Trachycephalus typhonius (Linnaeus, 1758)	11			x	x	x	x		
Leptodactylidae									
Adenomera hylaedactyla (Cope, 1868)	28		x	x	x	x	x		
Leptodactylus fuscus (Schneider, 1799)	23		x	x	x	x	x		
Leptodactylus pentadactylus (Laurenti, 1768)	4			x	x			x	
Leptodactylus podicipinus (Cope, 1862)	14	x	x		x		x		
Microhylidae									
Elachistocleis helianneae (Caramaschi, 2010)	5	x	x		x	x		x	
Pipidae									
Pipa pipa (Linnaeus, 1758)	2	x	x		x				x

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References

Araújo, A.S., Costa-Campos, C.E. (2014): Anurans of the Reserva Biológica do Parazinho, Municipality of Macapá, state of Amapá, eastern Amazon. Check List **10**: 1414–1419.

Ávila-Pires, T.C.S., Hoogmoed, M.S., Vitt, L.J. (2007): Herpetofauna da Amazônia. In: Herpetologia no Brasil. II, p. 13–43. Nascimento, L.B., Oliveira, M.E., Eds., Belo Horizonte, Brazil, Sociedade Brasileira de Herpetologia.

Ávila-Pires, T.C.S., Hoogmoed, M.S., Rocha, W.A. (2010): Notes on the vertebrates of northern Pará, Brazil: a forgotten part of the Guiana Region. I. Herpetofauna. Boletim do Museu Paraense Emílio Goeldi **5**: 13–112.

Ávila-Pires, T.C.S., Alves-Silva, K.R., Barbosa, L., Correa, F.S. Cosenza, J.F.A., Costa-Rodrigues, A.P.V., et al. (2018): Changes in amphibian and reptile diversity over time in Parque Estadual do Utinga, Pará State, Brazil, a protected area surrounded by urbanization. Herpetology Notes **11**: 499–512.

Ayres, M., Ayres, M., Jr., Ayres, D.L., Santos, A.A. (2007): Bioestat 5.3: Aplicações Estatísticas nas Áreas das Ciências Biomédicas. Belém, Pará, Brazil, Sociedade Civil Mamirauá.

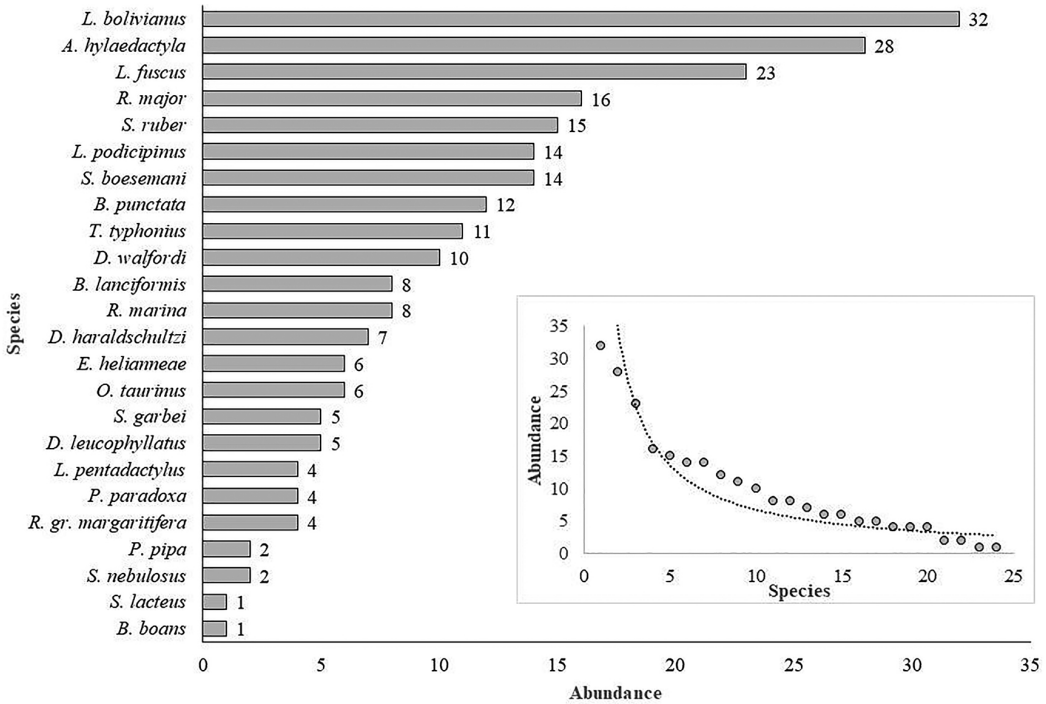

Figure 5. Whittaker diagram showing the relative abundance of the 24 frog species found on Santana Island, Amapá State, Brazil between October 2012 and August 2013. Bars represent relative abundance (%), numbers the total abundance of individuals of each species collected and observed.

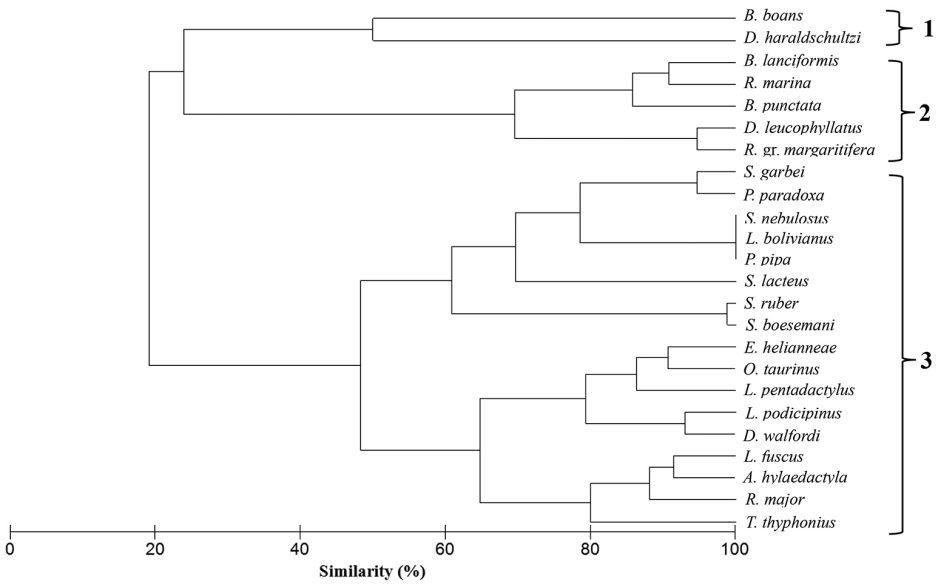

Figure 6. Rarefaction curve for anuran species on Santana Island, Amapá State, Brazil, based on the number of samples (days of field work). Species observed are denoted by triangles, Jackknife 1 estimates by circles, and Bootstrap estimates by squares.

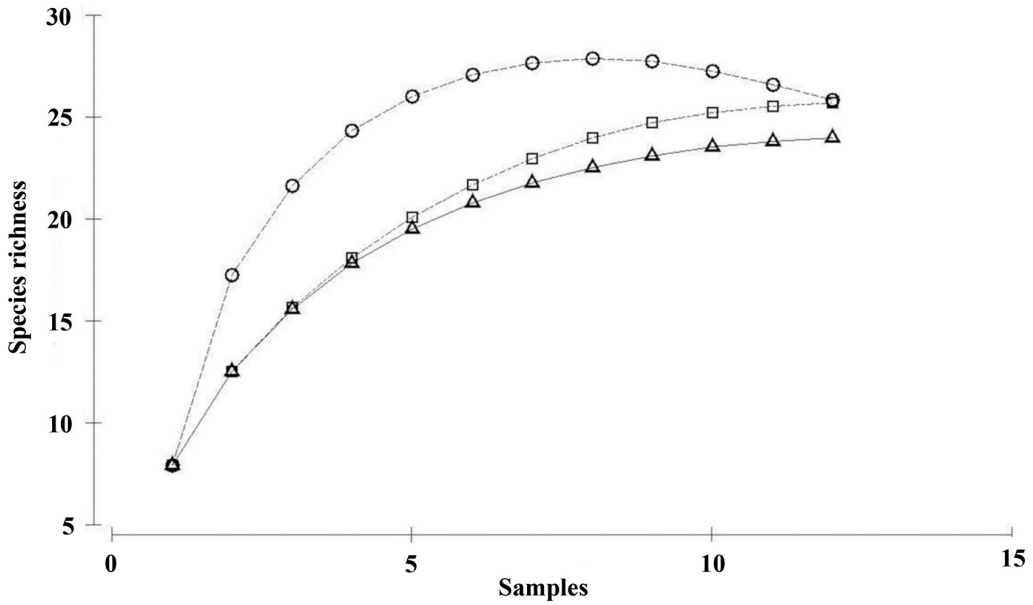

Figure 7. Dendrogram based on the Jaccard similarity index, comparing the anuran species composition of three areas on Santana Island, Amapá State, Brazil. Group 1 = upland forest, Group 2 = permanent pond, Group 3 = flooded forest.

Azevedo-Ramos, C., Galatti, U. (2002): Patterns of amphibian diversity in Brazilian Amazonia: conservation implications. Biological Conservation **103**: 103–111.

Benício, R.A., Lima, J.D. (2017): Anurans of Amapá National Forest, Eastern Amazonia, Brazil. Herpetology Notes **10**: 627–633.

Bernarde, P.S. (2007): Ambientes e temporada de vocalização da anurofauna no Município de Espigão do Oeste, Rondônia, Sudoeste da Amazônia, Brasil (Amphibia: Anura). Biota Neotropica **7**: 87–92.

Bernarde, P.S., Machado, R.A., Turci, L.C.B. (2011): Herpetofauna da área do Igarapé Esperança na Reserva Extrativista Riozinho da Liberdade, Acre, Brasil. Biota Neotropica **11**: 117–144.

Bernarde, P.S., Albuquerque, S., Miranda, D.B., Turci, L.C.B. (2013): Herpetofauna da floresta do baixo Rio Moa em Cruzeiro do Sul, Acre, Brasil. Biota Neotropica **13**: 220–244.

Bernardo, P.H., Guerra-Fuentes, R.A., Matiazzi, W., Zaher, H. (2012): Checklist of amphibians and reptiles of Reserva Biológica do Tapirapé, Pará, Brazil. Check List **8**: 839–846.

Campos, F.S., Brito, D., Solé, M. (2014): Diversity patterns, research trends and mismatches of the investigative efforts to amphibian conservation in Brazil. Anais da Academia Brasileira de Ciências **86**: 1873–1886.

Canelas, M.A.S., Bertoluci, J. (2007): Anurans of the Serra do Caraça, southeastern Brazil: species composition and phenological patterns of calling activity. Iheringia, Série Zoologia **97**: 21–26.

Colwell, R.K. (2013): EstimateS: statistical estimation of species richness and shared species from samples. Version 9. Available at: http://purl.oclc.org/estimates. Accessed on 4 April 2020.

Corrêa, J.G., Sousa, J.C., França, P.F., Costa-Campos, C.E. (2015): *Sphaenorhynchus carneus* (Cope, 1868) (Amphibia: Anura: Hylidae): distribution extension, geographic distribution map and new state record. Check List **11**(4): 1725.

Costa-Campos, C.E., Freire, E.M.X. (2015): Distribution extension and geographic distribution map of *Elachistocleis helianneae* (Anura: Microhylidae): new record for state of Amapá, Eastern Amazon. Check List **11**(5): 1747.

Costa-Campos, C.E., Freire, E.M.X. (2019): Richness and composition of anuran assemblages from an Amazonian savanna. Zookeys **843**: 149–169.

Costa-Campos, C.E., Gama, S.L., Galeno, E.O., Silva, D.W.S., Corrêa, K.J.G., Almeida, D.P., Santiago, A.G. (2014): New record and distribution map of *Hypsiboas lanciformis* (Cope, 1871) (Amphibia, Anura, Hylidae) in Eastern Amazonia, Brazil. Check List **10**: 960–961.

Costa-Campos, C.E., Freire, E.M.X., De Carvalho, T.R (2016): First record of *Pseudopaludicola boliviana* Parker, 1927 (Anura, Leptodactylidae, Leiuperinae) in the Brazilian state of Amapá, with comments on its advertisement call and distribution. Check List **12**(6): 1991.

Costa-Campos, C.E., Tavares-Pinheiro, R., Castroviejo-Fisher, S. (2020a): Amphibia, Anura, Centrolenidae, *Cochranella resplendens* (Lynch & Duellman, 1973): first record from Brazil and updated map of the geographic distribution. Check List **16**(4): 847–851.

Costa-Campos, C.E., Figueiredo, V.A.M.B., Lima, J.F.R., Lima, J.D. (2020b): New record and distribution map of the glassfrog *Vitreorana ritae* (Lutz, 1952) (Anura: Centrolenidae) from Amapá state, Eastern Amazon. Herpetology Notes **13**: 733–737.

Costa-Campos, C.E., Figueiredo, V.A.M.B., Jairam, R., Fouquet, A. (2020c): Distribution extension of *Rhinella lescurei* (Bufonidae) in the state of Amapá, Brazil. Herpetology Notes **13**: 801–804.

Costa-Campos, C.E., Bang, D.L., Figueiredo, V.A.M.B., Tavares-Pinheiro, R., Fouquet, A. (2021): New records and distribution extensions of the glassfrogs *Hyalinobatrachium taylori* (Goin, 1968) and *H. tricolor* Castroviejo-Fisher, Vilá, Ayarzagüena, Blanc & Ernst, 2011 (Anura, Centrolenidae) in Amapá, Brazil. Check List **17**(4): 637–642.

Crump, M.L., Scott, N.J., Jr. (1994): Visual encounter surveys. In: Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians, p. 84–91. Heyer, W.R., Donnelly, M.A.R., McDiarmid, W., Hayek, L.-A.C., Foster, M.S. Eds., Washington, DC, USA, Smithsonian Institution Press.

Dajoz, R. (1983): Ecologia Geral. Fourth Edition. Petrópolis, Brazil, Vozes.

Dias, I., Medeiros, T., Vila Nova, M., Solé, M. (2014): Amphibians of Serra Bonita, southern Bahia: a new hotpoint within Brazil's Atlantic Forest hotspot. ZooKeys **449**: 105–130.

Dias-Souza, M.R., Figueiredo, V.A.M.B., Tavares-Pinheiro, R., Costa-Campos, C.E. (2021): Filling gap and new state record of *Lithodytes lineatus* (Schneider, 1799) (Anura, Leptodactylidae) from the eastern Brazilian Amazon. Check List **17**(1): 95–101.

EMBRAPA [Empresa Brasileira de Pesquisa Agropecuária] (1996): Caracterização e mapeamento dos solos da Ilha de Santana, Estado do Amapá. Belém, Pará, Brazil, Centro de Pesquisa Agroflorestal da Amazônia Oriental.

Eterovick, P.C., Carnaval, A.C.O.Q., Borges-Nojosa, D.M., Silvano, D.L., Segalla, M.V., Sazima, I. (2005): Amphibian declines in Brazil: an overview. Biotropica **37**: 166–179.

Fearnside, P.M. (2005): Deforestation in Brazilian Amazonia: history, rates and consequences. Conservation Biology **19**: 680–688.

Figueiredo, V.A.M.B., Tavares-Pinheiro, R., Freitas, A.P., Dias-Souza, M.R., Costa-Campos, C.E. (2020): First records of the glass frogs *Hyalinobatrachium cappellei* (van Lidth de Jeude, 1904) and *H. mondolfii* Señaris & Ayarzagüena, 2001 (Anura, Centrolenidae) in the state of Amapá, Brazil. Check List **16**(5): 1369–1374.

Figueiredo, V.A.M.B., Tavares-Pinheiro, R., Pinheiro-Freitas, A., Costa-Campos, C.E. (2021): New geographic record for *Osteocephalus leprieurii* (Duméril & Bibron, 1841) (Anura, Hylidae) from Amapá State, northern Brazil. Herpetology Notes **14**: 827–831.

Fonseca, W.L., Silva, J.D., Abegg, A.D., Rosa, C.M., Bernarde, P.S. (2019): Herpetofauna of Porto Walter and surrounding areas, southwest Amazonia, Brazil. Herpetology Notes **12**: 91–107.

Freitas, J.L. (2008): Sistemas agroflorestais e sua utilização como instrumento de uso da terra: o caso dos pequenos agricultores da Ilha de Santana, Amapá, Brasil. Unpublished PhD thesis, Universidade Federal Rural da Amazônia, Belém, Pará.

Freitas, J.L., Santos, M.M.L.S., Oliveira, F.A. (2010): Fenologia reprodutiva de espécies potenciais para arranjo em sistemas agroflorestais, na Ilha de Santana, Amapá. Revista de Ciências Agrárias **53**(1): 78–86.

Freitas, M.A., Vieira, R.S., Entiauspe-Neto, O.M., Oliveira e Sousa, S., Farias, T., Sousa, A.G., Moura, G.J.B. (2017): Herpetofauna of the northwest Amazon forest in the state of Maranhão, Brazil, with remarks on the Gurupi Biological Reserve. ZooKeys **643**: 141–155.

Freitas, M.A., Venâncio, N.M., Abegg, A.D., Azevedo, W.S., Pereira, V.O., Zanotti, A.P., et al. (2020): Herpetofauna from the Estação Ecológica Rio Acre, Amazon Rainforest, Brazil. Herpetology Notes **13**: 33–48.

Funk, W.C., Caminer, M., Ron, S.R. (2012): High levels of cryptic species diversity uncovered in Amazonian frogs. Proceedings of the Royal Society B, Biological Sciences **279**: 1806–1814.

Haffer, J. (2008): Hypotheses to explain the origin of species in Amazonia. Brazilian Journal of Biology **68**: 917–947.

Hammer, O., Harper, D.A.T., Ryan, P.D. (2001): PAST Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica **4**: 1–9.

Heyer, W.R., Donnelly, M.A., McDiarmid, R.W., Hayek, L.-A.C., Foster, M.S. (1994): Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Washington, D.C., USA, Smithsonian Institution Press.

ICMBio [Instituto Chico Mendes de Conservação da Biodiversidade] (2018): Livro Vermelho da Fauna Brasileira Ameaçada de Extinção. Brasília, Brazil, ICMBio/MMA.

IUCN [International Union for Conservation of Nature] (2020): The IUCN Red List of Threatened Species. Version 2021-1. Available at: https://www.iucnredlist.org. Accessed on 17 April 2020.

Knispel, S.R., Barros F.B. (2009): Anfíbios anuros da região urbana de Altamira (Amazônia Oriental), Pará, Brasil. Biotemas **22**(2): 191–194.

Kopp, K., Signorelli, L., Bastos, R.P. (2010): Distribuição temporal e diversidade de modos reprodutivos de anfíbios anuros no Parque Nacional das Emas e entorno, estado de Goiás, Brasil. Iheringia, Série Zoologia **100**: 192–200.

Lima, J.R.F., Lima, J.D., Lima, S.D., Lima-Silva, R.B., Andrade, G.V. (2017): Amphibians found in the Amazonian savanna of the Rio Curiaú Environmental Protection Area in Amapá, Brazil. Biota Neotropica **17**: 1–10.

Lima, J.R.F., Lima, J.D., Sousa, J.C., Oliveira, S.H., Costa-Campos, C.E. (2019): *Hydrolaetare schmidti* (Cochran & Goin, 1959): new records for Amapá State, eastern Amazon and a geographic distribution map. Check List **15**: 815–819.

Magurran, A.E. (2011): Medindo a Diversidade Biológica. Curitiba, Brazil, Editora UFPR.

Mendes-Pinto, T.J., Souza, S.M. (2011): Preliminary assessment of amphibians and reptiles from Floresta Nacional do Trairão, with a new snake record for the Pará State, Brazilian Amazon. Salamandra **47**: 199–206.

Menin, M., Carvalho, V.T., Almeida, A.P., Gordo, M., Oliveira, D.P., Luiz, L.F., et al. (2017): Amphibians from Santa Isabel do Rio Negro, Brazilian Amazonia. Phyllomedusa **16**: 183–199.

Menin, M., Ferreira, R.F.B., Melo, I.Z., Gordo, M., Hattori, G.Y., Sant'anna, B.S. (2019): Anuran diversity in urban and rural zones of the Itacoatiara municipality, central Amazonia, Brazil. Acta Amazonica **49**(2): 122–130.

Miranda, D.B., Albuquerque, S., Turci, L.C.B., Bernarde, P.S. (2015): Richness, breeding environments and calling activity of the anurofauna of the lower Moa River forest, state of Acre, Brazil. Zoologia **32**: 93–108.

Missassi, A.F.R., Costa-Campos, C.E., Lima, J.D., Lambertini, C. (2017): Range extension of the poorly know tree frog *Dendropsophus haraldschultzi* (Bokermann, 1962) (Amphibia, Anura, Hylidae): first records for two Brazilian Amazon states. Herpetology Notes **10**: 703–707.

Nogueira, C., Valdujo, P.H., Paese, A., Ramos Neto, M.B., Machado, R.B. (2009): Desafios para a identificação de áreas para conservação da biodiversidade. Megadiversidade **5**: 43–53.

Pedroso-Santos, F., Sanches, P.R., Costa-Campos, C.E. (2019): Anurans and reptiles of the Reserva Extrativista Beija-Flor Brilho de Fogo, Amapá State, eastern Amazon. Herpetology Notes **12**: 799–807.

Pereira-Júnior, A.P., Costa-Campos, C.E., Araújo, A.S. (2013): Composição e diversidade de anfíbios anuros do campus da Universidade Federal do Amapá. Biota Amazônia **3**: 13–21.

Piatti, L., Amaro, P.M.O., Araújo, J.F.J., Sanches, V.Q.A., Bernarde, P.S. (2012): Anurans of a disturbed area in Jarú, Rondônia, Brazil. Check List **8**: 83–87.

Pirani, R.M., Werneck, F.P., Thomaz, A.T., Kenney, M., Sturaro, M.J., Ávila-Pires, T.C.S., et al. (2019): Testing main Amazonian rivers as barriers across time and space within widespread taxa. Journal of Biogeography **2019**: 1–13.

Prudente, A.L.C., Sturaro, M.J., Travassos, A.E.M., Maschio, G.F., Santos-Costa, M.C. (2013): Anurans of the Urucu Petrol Basin, municipality of Coari, State of Amazonas, northern Brazil. Check List **9**: 601–606.

Queiroz, S.S., Silva, A.R., Reis, F.M., Lima, J.D., Lima, J.R.F. (2011): Anfíbios de uma área de castanhal da Reserva Extrativista do Rio Cajari, Amapá. Biota Amazônia **1**: 1–18.

Ramalho, W.P., Andrade, M.S., Matos, L.R.A., Vieira, L.J.S. (2016): Amphibians of varzea environments and floating meadows of the oxbow lakes of the Middle Purus River, Amazonas, Brazil. Biota Neotropica **16**: 1–15.

Saraiva, J.F., Maitra, A., Galardo, A.K.R., Scarpassa, V.M. (2019): First record of *Aedes* (*Stegomyia*) *albopictus* in the state of Amapá, northern Brazil. Acta Amazonica **49**(1): 71–74.

Segalla, M.V., Berneck B., Canedo C., Caramaschi, U., Cruz, C.A.G., Garcia, P.C.A., et al. (2021): Brazilian amphibians: list of species. Herpetologia Brasileira **10**(1): 121–216.

Silva, R.A., Xavier, S.L.O., Souza Filho, M.F., Silva, W.R., Nascimento, D.B., Deus, E.G. (2007): Frutíferas hospedeiras e parasitóides (Hym., Braconidae) e *Anastrepha* spp. (Dip., Tephritidae) na Ilha de Santana, Estado do Amapá, Brasil. Arquivos do Instituto Biológico **74**(2): 153–156.

Silva e Silva, Y.B., Costa-Campos, C.E. (2014): *Scinax garbei* (Miranda–Ribeiro, 1926) (Amphibia: Anura: Hylidae): distribution extension for Brazilian Amazonia and first record in the state of Amapá. Check List **10**: 448–449.

Silva e Silva, Y.B., Costa-Campos, C.E. (2016): *Hyalinobatrachium iaspidiense* (Ayarzaguena, 1992) (Anura: Centrolenidae): first record in Amapá State, Brazil and geographic distribution map. Check List **12**(2): 1849.

Silva e Silva, Y.B., Costa-Campos, C.E. (2018): Anuran species composition of Cancão Municipal Natural Park, Municipality of Serra do Navio, Amapá State, Brazil. ZooKeys **762**: 131–148.

Simões, P.I., Rojas-Runjaic, F.J.M., Gagliardi-Urrutia, G., Castroviejo-Fisher, S. (2019): Five new country records of Amazonian anurans for Brazil, with notes on morphology, advertisement calls, and natural history. Herpetology Notes **12**: 211–219.

Valente, M.A., Oliveira-Júnior, R.C., Rodrigues, T.E., Santos, P.L., Silva, J.M.L., Cardoso-Júnior, E.Q. (1998): Solos da Ilha de Santana, Município de Santana, Estado do Amapá. Belém, Pará, Brazil, Embrapa-CPATU.

Vasconcelos, T.S., Santos, T.G., Haddad, C.F.B., Rossa-Feres, D.C. (2010): Climatic variables and altitude as predictors of anuran species richness and number of reproductive modes in Brazil. Journal of Tropical Ecology **26**: 423–432.

Vaz-Silva, W., Oliveira, R.M., Gonzaga, A.F.N., Pinto, K.C., Poli, F.C., Bilce, T.M., 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.

Venâncio, N.M., Souza, M.B. (2016): Anfíbios do Parque Ambiental Chico Mendes, Rio Branco, Acre, Brasil. Biotemas **29**: 85–95.

Vilhena, J.E.S. (2017): Etnoconhecimento dos fenômenos metereológicos na Ilha de Santana, Amapá, Brasil. Unpublished PhD thesis, Universidade Federal do Amapá, Macapá, Amapá, Brazil.

Waldez, F., Menin, M., Vogt, R.C. (2013): Diversidade de anfíbios e répteis Squamata na região do baixo Rio Purus, Amazônia Central, Brasil. Biota Neotropica **13**: 300–316.

Young, B., Lips, K.R., Reaser, J.K., Ibáñez, R., Salas, A.W., Cedeño, J.R., et al. (2001): Population declines and priorities for amphibian conservation in Latin America. Conservation Biology **15**: 1213–1223.

Zimmerman, B.L. (1994): Audio strip transects. In: Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians, p. 92–97. Heyer, W.R., Donnelly, M.A., McDiarmid, R.W., Hayek, L.-A.C., Foster, M.S., Eds., Washington, D.C., USA, Smithsonian Institution Press.

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