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HERPETOFAUNAL ASSEMBLAGES IN A REGION FROM THE BELÉM AREA OF ENDEMISM, PARÁ STATE, EASTERN AMAZONIA, BRAZIL

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ABSTRACT

We present a list of amphibians and reptiles collected during six field surveys in the municipalities of Tailândia, Tomé-Açu and Moju, region of the Belém area of endemism, eastern Amazonia, Brazil. We conducted surveys on several fragments of the Amazon rainforest located in a matrix of palm oil plantations (*Elaeis guineensis*) and/or old pastures recently removed for new plantations. A total of 108 species, including amphibians (50), turtles (3), crocodiles (2), amphisbaenians (3), lizards (22) and snakes (28) were identified. Our results show a phylogenetic pattern already known for the Amazon, with Hylidae and Leptodactylidae presenting higher species richness among amphibians, Gymnophthalmidae and Teiidae for lizards, and Dipsadidae and Colubridae among snakes. Despite the study areas being inserted within the "arc of deforestation" in northeastern Pará state, where fragmented forest can be found in a matrix of palm oil plantations, pastures and regenerating forests, it still harbors a high diversity of reptiles and amphibians. Large-scale, agribusiness palm oil plantations are expanding in the region, and actions are needed to minimize impacts on local fauna. For this, conservation efforts focused on the remaining fragments of forest are crucial to protect the high species diversity still found in the region.

Key words: Amazon Forest; forest fragments; amphibians; reptiles; palm oil plantations.

RESUMEN

Ensamble de la herpetofauna en la región endémica de Belém, Estado de Pará, Este del Amazonas, Brasil. Presentamos una lista de anfibios y reptiles colectados en seis muestreos realizados en los municipios de Tailândia, Tomé-Açu y Moju, una región de endemismos de Belém, en el este de la Amazonia (Brasil). Realizamos los muestreos en diversos fragmentos de selva amazónica localizados en una matriz de cultivos de palma aceitera (*Elaeis guineensis*) y/o pasturas recientemente removidas para destinarlas a nuevas plantaciones. Fue

identificado un total de 108 especies, incluyendo anfibios (50), tortugas (3), cocodrilos (2), anfisbenas (3), lagartos (22) y serpientes (28). Nuestros resultados muestran un patrón filogenético ya conocido para la Amazonia, con la mayor riqueza de especies pertenecientes a las Familias Hylidae y Leptodactylidae entre los anfibios; Gymnophthalmidae y Teiidae en los lagartos; y Dipsadidae y Colubridae entre las serpientes. A pesar que el área de estudio está inserta dentro del "arco de deforestación" en el noreste del estado de Pará, donde se encuentra la selva fragmentada en una matriz de cultivos de palma aceitera, pasturas y bosques en regeneración; la misma alberga una alta diversidad de reptiles y anfibios. Los agronegocios con palmas aceiteras a gran escala se están expandiendo en la región, y se necesitan acciones para minimizar los impactos sobre la fauna local. Para ello, los esfuerzos de conservación enfocados en los fragmentos remanentes de selva, son cruciales para proteger la alta diversidad de especies que aún se encuentra en esta región.

Palabras Clave: Selva Amazónica; fragmentos de bosque; anfibios; reptiles; plantaciones de palma aceitera.

INTRODUCTION

The Amazon Forest harbors one of the greatest diversities of animals on Earth (Silva and Garda, 2011; Rabosky, von May, Grundler and Rabosky, 2019), including over 700 species of amphibians and reptiles, with high levels of endemism within these groups (Prudente, 2017; Hoogmoed, 2019; Ávila-Pires, 2020). This number is increasing mainly due to the discovery and description of new species for this biome (Oliveira et al., 2018; Ferrão, Moravec, Hanken and Lima et al., 2020; Mângia, Koroiva and Santana, 2020).

Amphibians and reptiles are among the most threatened vertebrates according to Brazilian and international red lists (MMA, 2014; IUCN, 2021). Degradation of natural habitats, leading to population declines or local species extinctions, can produce irreversible damages to populations and to the genetic diversity of a species (Verdade, Dixo and Curcio, 2010; Ribeiro-Júnior and Amaral, 2016). Furthermore, considering large number of cryptic species in Amazonia (Fouquet, Cassini, Haddad, Pech and Rodrigues, 2014; Pirani et al., 2020; Ribeiro-Júnior et al., 2020; Ribeiro-Júnior, Meiri and Fouquet, 2020), many species will likely disappear without before being formally described. Studies in areas never sampled before – even nearby big cities – are helping uncover this diversity and fill knowledge gaps (Linnean and Wallacean shortfalls, Hortal et al., 2015).

The northeast of Pará State, inserted in the Belém Area of Endemism (Silva, Rylands, and Fonseca, 2005), is the most deforested and less protected area of the Brazilian Amazon (Garda, Silva and Baião, 2010). After a long history of logging and cattle raising, the area is now under strong pressure by the expansion of palm oil plantations (*Eleae guineensis*), which is promoting a rapid change of land use. It is urgent, therefore, to establish a baseline for the diversity of the region and, hence, provide adequate data to monitor possible biodiversity impacts of such land use changes. We provide the results of the first field samplings in nine areas in the municipalities of Tailândia, Moju and Tomé-Açu, northeast of Pará state, Brazil (in the Belém Area of Endemism).

MATERIALS AND METHODS

The study area is located in the Tocantins-Capim interfluve, in the Belém Area of Endemism (see Silva et al., 2005), where we sampled nine points distributed in three municipalities: Tailândia, Moju and Tomé-Açu, Pará State, eastern Brazilian Amazonia (Fig. 1; Table 1). The sampling areas cover a wide variety of environments, such as riparian areas, upland ("Terra Firme"), fragmented forests, and palm oil plantations (Figs. 2–5). Except for the plantations, the vegetation of the other areas is classified as secondary forests at different successional stages. The primitive vegetation has been replaced by pastures and/or palm oil plantations (*Elaeis guineensis*).

The climate is humid equatorial, type Am in the Köppen classification, with two well-defined seasons, one drier (June-November), and an intense rainy season (December-May) with average annual precipitation up to 2500 mm (Albuquerque, Souza, Oliveira and Souza, 2010). The average annual temperature is around 26ºC and mean relative air humidity approximately 85% (Oliveira et al., unpublished results).

Sampling techniques included visual and acoustic active searches, and pitfall traps with drift fences (Ribeiro-Júnior, Gardner and Ávila-Pires, 2008; Ribeiro-Júnior, Rossi, Miranda and Ávila-Pires, 2011), using previously existing trails. Active searches were conducted both during day and night, in all sampling sites, between 8-12 a.m. or 14-17 p.m during the day, and 19-22 p.m. by two to four researchers.

Each pitfall trap array was composed of four buckets (30-liter buckets disposed in a Y shape). In Tailândia, pitfall traps were installed along each of the 17 sampling sites. Each pitfall trap array was set 100 m apart. At PPBIO, in Moju, twenty-five pitfall arrays were established in one sampling site (a less disturbed fragment with greater diversity of breeding sites for frogs), and each pitfall array was set at least 15 m apart. At Fazenda Maisa, also in Moju Municipality, fifteen pitfall traps were established in

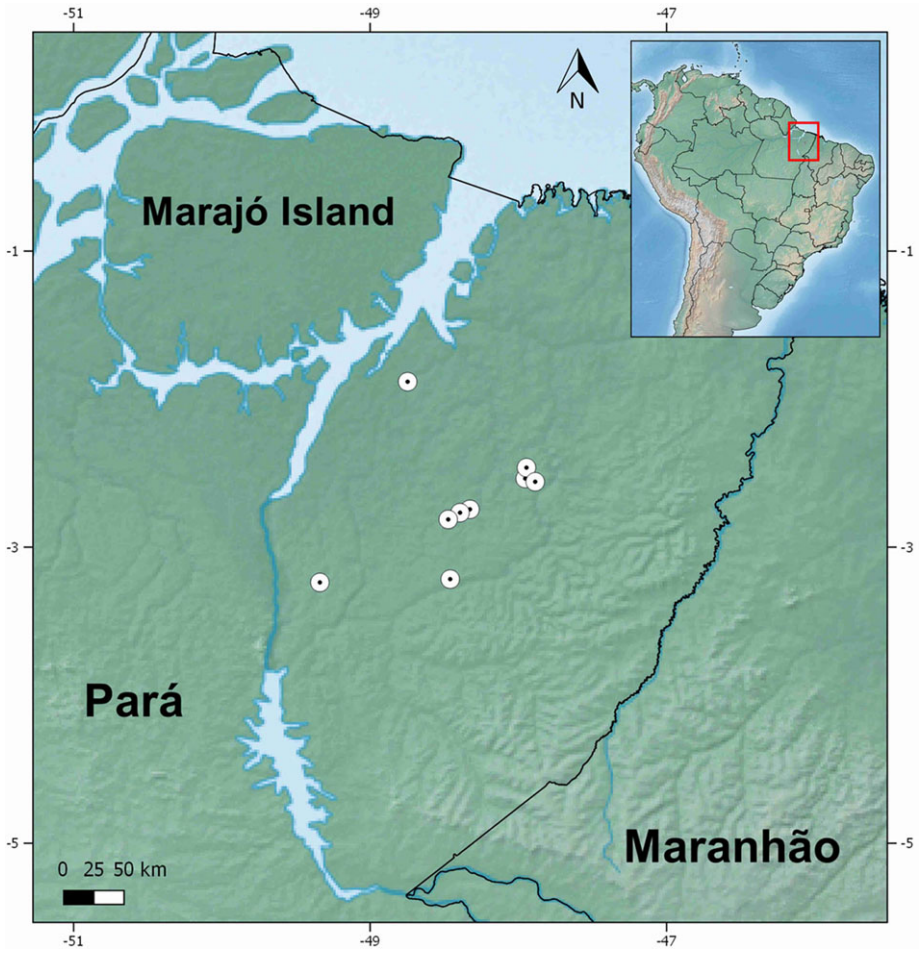

Fig. 1. Geographic location of the sites sampled in the present study in the eastern region of Belém Area of Endemism, eastern Amazonia, Pará state, Brazil.

one sampling site, and each array was set 100 m apart. In Tomé-Açu area no traps were installed, and only active surveys were performed. All trails and most pitfalls were georeferenced, but we here only present the coordinates in the central bucket from each pitfall trap (Table 1). Taxonomy follows Segalla et al. (2021) for amphibians, Uetz, Freed, Aguilar and Hošek (2021) for reptiles, except for Alopoglossidae, which we followed Ribeiro-Júnior et al. (2020a).

Data collection was carried out under permits 19828-4 and 12420-2 issued by Instituto Brasileiro de Meio Ambiente e Recursos Naturais Renováveis (IBAMA). Voucher specimens were killed with lydocaine, preserved in 10% formalin, and later stored in 70% ethanol (Appendix 1). Tissue samples were taken prior to voucher preservation with formalin and stored in 100% ethanol in cryotubes for future DNA sequencing. Voucher specimens were deposited in the following collections: Coleção Herpetologica of Museu Paraense Emílio Goeldi (MPEG) in Belém, Pará, Brazil, Coleção Herptológica of Universidade de Brasília (CHUNB) in Brasília, Brazil, and Coleção da Universidade Federal da Paraíba (CHUFPB), in João Pessoa, Paraíba, Brazil.

RESULTS

We recorded 108 species in the study area: 48 anurans, one caecilian, one salamander, three amphisbaenians, 22 lizards, 28 snakes, two alligators, and three turtles. Among amphibians, Hylidae presented the highest richness (19 species, 38% of the total number of species) (Table 2, Figs. 6–37), followed by Leptodactylidae (12 species, 24%), Bufonidae (six species, 12%), and Phyllomedusidade (four species, 8%). Other families found were Dendrobatidae (two species), and Aromobatidae, Ceratophryidae, Microhylidae, Pipidae, Plethodontidae, and Typhlonectidae with one species each.

Among reptiles (Figs. 38–73), we registered 22

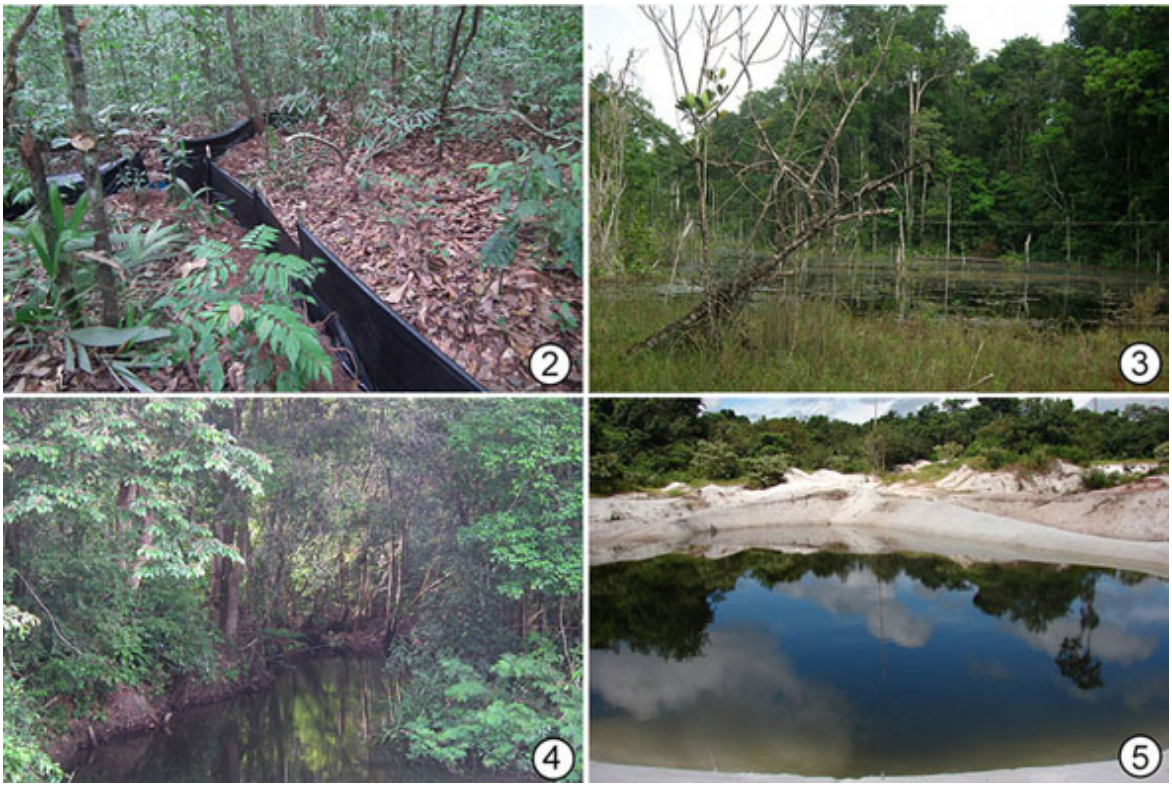

Fig. 2–5. Sampled areas in Pará state, eastern Amazonia, Brazil. 2: Pitfall trap array in Moju, Maisa Farm. 3: Pond in Maisa Farm. 4: Gallery forest in Maisa Farm. 5: Pond in Agropalma.

Table 1. Sampling areas in the municipalities of Moju, Tailândia, and Tomé-Açu, Pará state, Brazil.

	Locality	Municipality	Coordinates	Period
1	Agropalma	Tailândia	3 to 16 April 2008 03º13'00"S, 48º27'38"W 23 to 7 December 2012	2 to 21 April 2012
2	PPBio	Moju	01º52'59"S, 48º44'52"W	09 to 27 January 2011
3	Alvorada Farm	Tomé-Açu	02º32'13"S, 47º56'76"W	13 to 17 July 2012
4	São José Farm	Tomé-Açu	02º27'48"S, 47º56'45"W	13 to 17 July 2012
5	Canaã Farm	Tomé-Açu	02º33'32"S, 47º53'17"W	13 to 17 July 2012
6	Colorado Farm	Tomé-Açu	02º44'42"S, 48º19'38"W	13 to 17 July 2012
7	Acapu Farm	Tomé-Açu	02º46'04"S, 48º23'39"W	13 to 17 July 2012
8	Santo Antônio Farm	Tomé-Açu	02º48'48"S, 48º28'26"W	13 to 17 July 2012
9	Maisa Farm	Moju	03º14'20"S, 49º20'23"W	13 to 22 October 2012

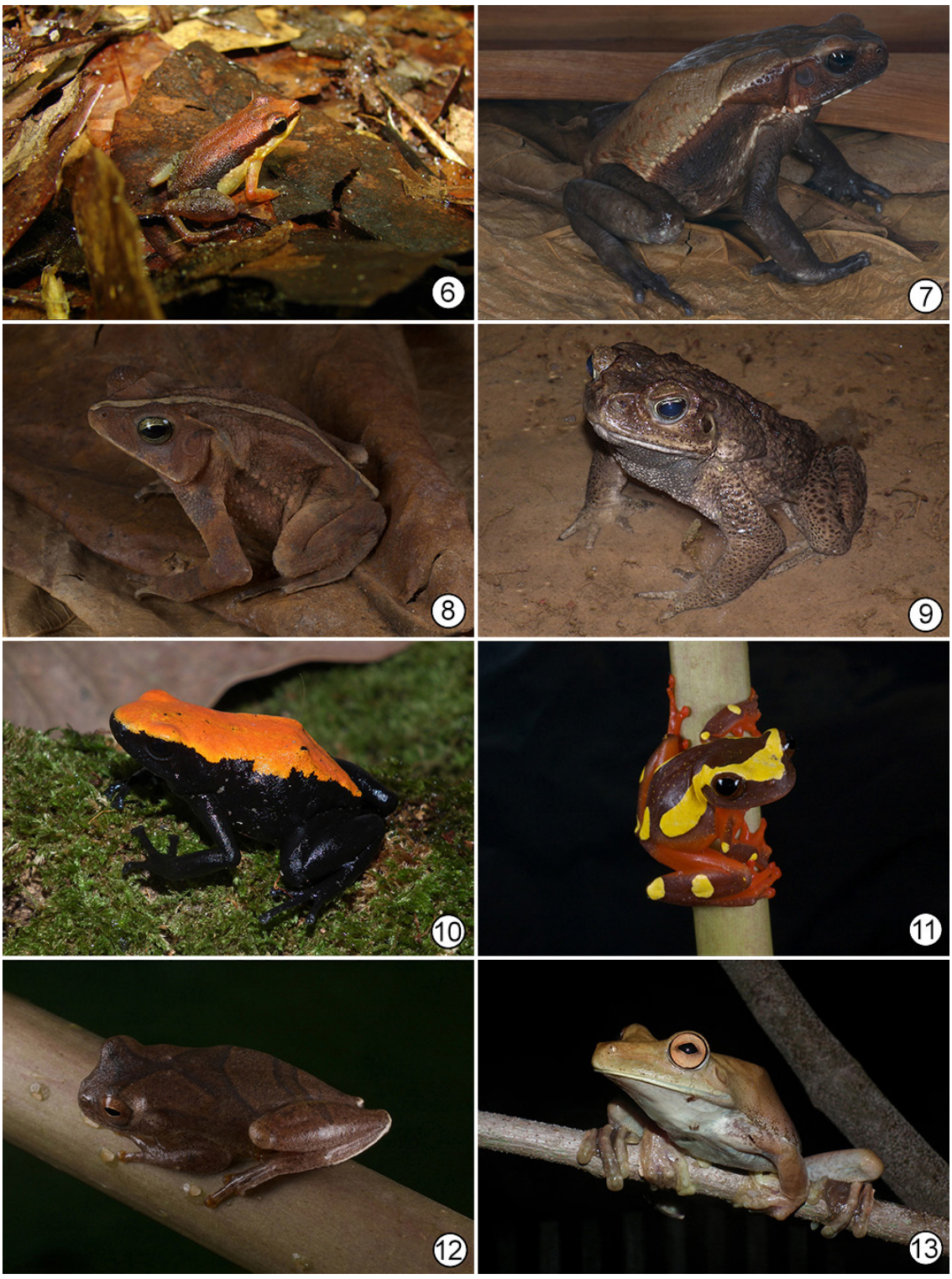

Fig. 6–13. Amphibians recorded during fieldwork in Tailândia, Tomé-Açu, and Moju municipalities, Pará state, Brazil. 6: *Allobates crombiei*. 7: *Rhaebo guttatus*. 8: *Rhinella* gr. *margaritifera*. 9: *Rhinella marina.* 10: *Adelphobates galactonotus*. 11: *Dendropsophus leucophyllatus*. 12: *Dendropsophus minutus*. 13: *Boana boans*.

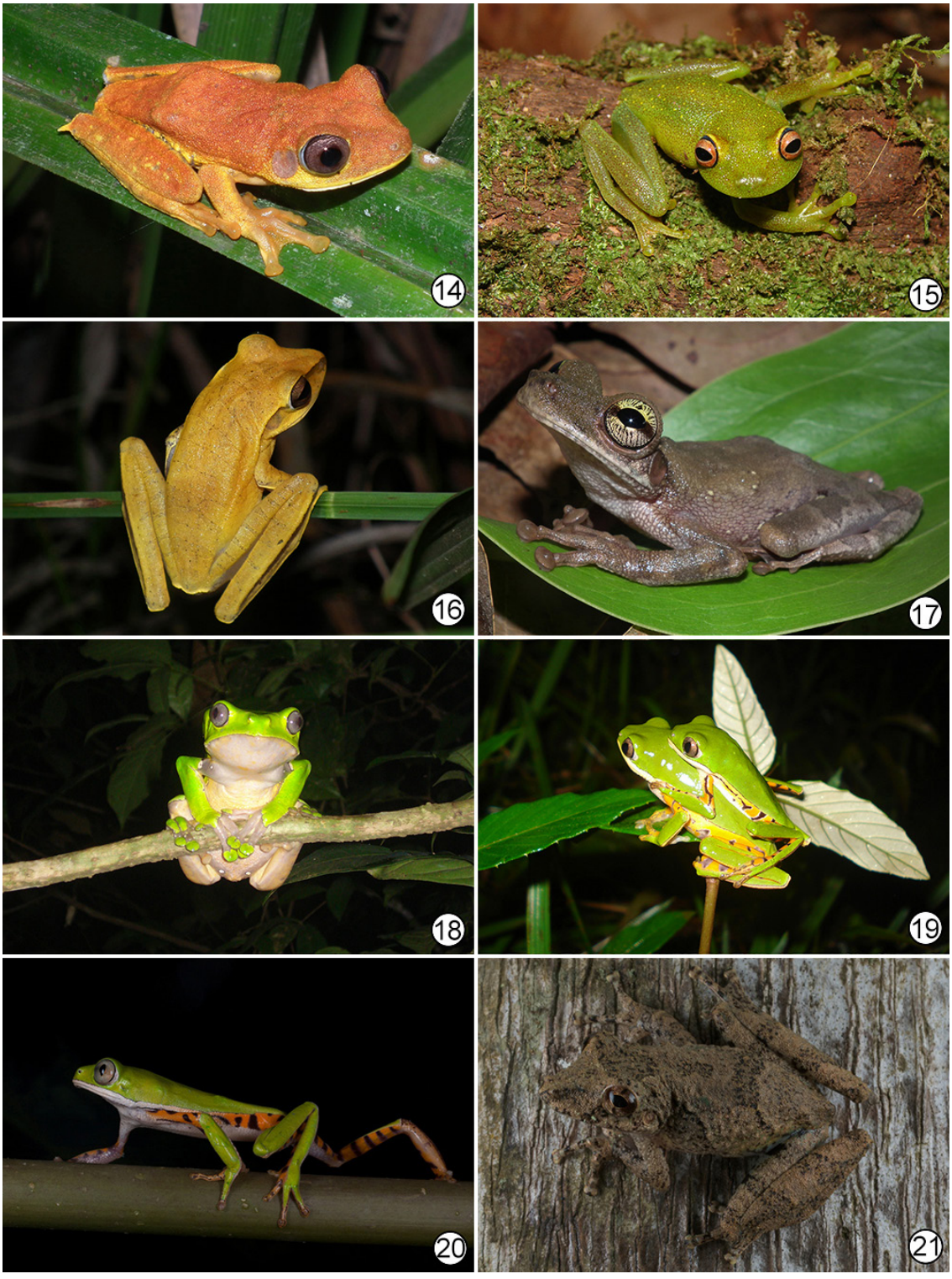

Fig. 14–21. Amphibians recorded during fieldwork in Tailândia, Tomé-Açu, and Moju municipalities, Pará state, Brazil. 14: *Boana calcarata*. 15: *Boana cinerascens*. 16: *Boana multifasciata*. 17: *Osteocephalus oophagus*. 18: *Phyllomedusa bicolor*. 19: *Pithecopus hypochondrialis* (amplex). 20: *Pithecopus hypochondrialis*. 21: *Scinax rostratus*.

Fig. 22–29. Amphibians recorded during fieldwork in Tailândia, Tomé-Açu, and Moju municipalities, Pará state, Brazil. 22: *Scinax ruber*. 23: *Scinax nebulosus*. 24: *Trachycephalus typhonius*. 25: *Adenomera andreae*. 26: *Adenomera hylaedactyla*. 27: *Leptodactylus fuscus*. 28: *Leptodactylus macrosternum*. 29: *Leptodactylus mystaceus*.

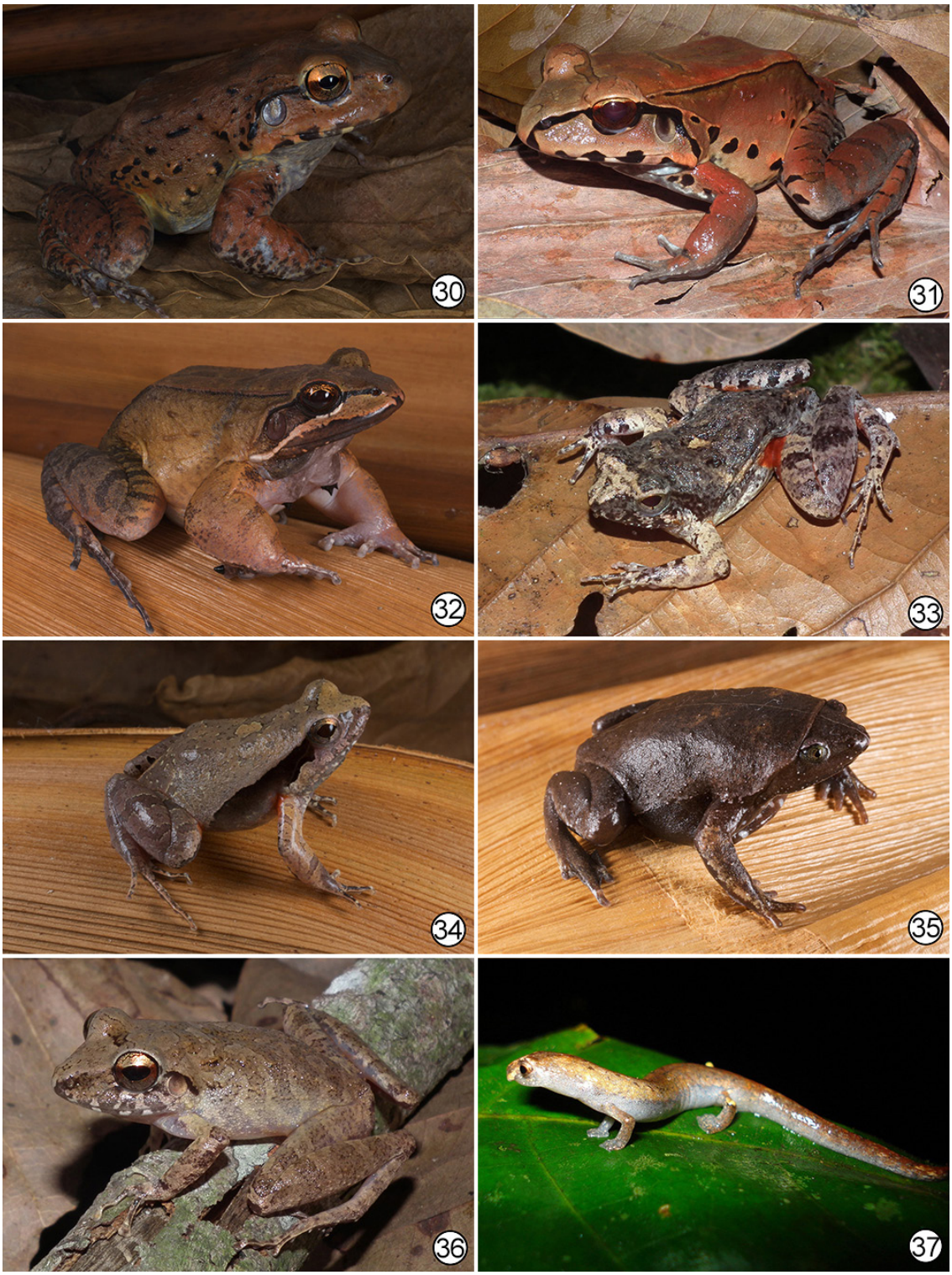

Fig. 30–37. Amphibians recorded during fieldwork in Tailândia, Tomé-Açu, and Moju municipalities, Pará state, Brazil. 30: *Leptodactylus paraensis*. 31: *Leptodactylus pentadactylus*. 32: *Leptodactylus rhodomystax*. 33: *Physalaemus ephippifer*. 34: *Physalaemus ephippifer*. 35: *Ctenophryne geayi*. 36: *Pristimantis* cf. *moa*. 37: *Bolitoglossa paraensis*.

Table 2. Amphibians registered in the municipalities of Moju, Tailândia, and Tomé-Açu, Pará state, Brazil. Sites: 1) Agropalma, 2) PPBio, 3) Alvorada Farm, 4) São José Farm, 5) Canaã Farm, 6) Colorado Farm, 7) Acapu Farm, 8) Santo Antônio Farm, and 9) Maísa Farm.

	Taxa	1	2	3	4	5	6	7	8	9
	Aromobatidae									
1	*Allobates crombiei* (Morales, 2002)	X	X							
2	*Allobates* sp.	X			X				X	
	Bufonidae									
3	*Amazophrynella xinguensis* Rojas, Fouquet, Ron, Hernandez-Ruz, Melo-Sampaio, Chaparro, Vogt, Carvalho, Pinheiro, Ávila, Farias, Gordo and Hrbek, 2018	X			X	X				
4	*Rhaebo guttatus* (Schneider, 1799)		X							
5	*Rhinella* cf. *magnussoni*			X						
6	*Rhinella major* (Muller and Herlmich, 1936)	X	X							
7	*Rhinella* gr. *margaritifera*	X	X							
8	*Rhinella marina* (Linnaeus, 1758)	X	X	X	X	X	X	X	X	X
	Ceratophryidae									
9	*Ceratophrys cornuta* (Linnaeus, 1758)	X								
	Craugastoridae									
10	*Pristimantis* cf. *moa*	X	X							X
	Dendrobatidae									
11	*Adelphobates galactonotus* (Steindachner, 1864)	X	X	X						
	Hylidae									
12	*Boana boans* (Linnaeus, 1758)	X	X							X
13	*Boana calcarata* (Troschel in Schomburgk, 1848)									X
14	*Boana cinerascens* (Spix, 1824)	X	X							X
15	*Boana* aff. *semilineata*	X		X	X	X	X	X	X	
16	*Boana multifasciata* (Günther, 1859"1858")	X	X	X	X	X	X		X	X
17	*Dendropsophus leucophyllatus* (Beireis, 1783)	X	X	X	X	X	X	X	X	
18	*Dendropsophus microcephalus* (Cope, 1886)		X							
19	*Dendropsophus minutus* (Ahl, 1933)	X	X							X
20	*Dendropsophus nanus* (Boulenger, 1889)	X								
21	*Osteocephalus leprieurii* (Duméril and Bibron, 1841)	X								
22	*Osteocephalus oophagus* Jungfer and Schiesari, 1995	X	X							X
23	*Osteocephalus taurinus* Steindachner, 1862	X								X
24	*Scinax boesemani* (Goin, 1966)	X								
25	*Scinax fuscovarius* (A. Lutz, 1925)		X							
26	*Scinax nebulosus* (Spix, 1824)			X	X	X	X	X	X	
27	*Scinax rostratus* (Peter, 1863)	X	X							
28	*Scinax* gr. *ruber*	X								X
29	*Trachycephalus resinifictrix* (Goeldi, 1907)	X	X							
30	*Trachycephalus typhonius* (Linnaeus, 1758)	X	X							X
	Leptodactylidae									
31	*Adenomera andreae* (Müller, 1923)	X	X							X

Table 2. Cont.

	Taxa	1	2	3	4	5	6	7	8	9
32	*Adenomera hylaedactyla* (Cope, 1868)	X								X
33	*Leptodactylus fuscus* (Schneider, 1799)	X	X							X
34	*Leptodactylus knudseni* Heyer, 1972									X
35	*Leptodactylus macrosternum* Miranda-Ribeiro, 1926	X	X	X	X	X	X	X	X	X
36	*Leptodactylus mystaceus* (Spix, 1824)	X	X							
37	*Leptodactylus paraensis* Heyer, 2005	X	X							
38	*Leptodactylus pentadactylus* (Laurenti, 1768)	X								X
39	*Leptodactylus petersii* (Steindachner, 1864)	X	X							
40	*Leptodactylus rhodomystax* Boulenger, 1884“1883”		X							
41	*Physalaemus ephippifer* (Steindachner, 1864)	X	X	X		X	X	X	X	X
42	*Pseudopaludicola mystacalis* (Cope, 1887)	X	X							
	Microhylidae									
43	*Ctenophryne geayi* Mocquard, 1904	X	X							
	Phyllomedusidae									
44	*Phyllomedusa bicolor* (Boddaert, 1772)	X								
45	*Phyllomedusa tomopterna* (Cope, 1868)	X								
46	*Phyllomedusa vaillantii* Boulenger, 1882	X								X
47	*Pithecopus hypochondrialis* (Daudin, 1800)	X								
	Pipidae									
48	*Pipa pipa* (Linnaeus, 1758)	X								
	Plethodontidae									
49	*Bolitoglossa paraensis* (Unterstein, 1930)	X								
	Typhlonectidae									
50	*Typhlonectes compressicauda* (Duméril and Bibron, 1841)	X	X							
	Total	**42**	**30**	**8**	**9**	**7**	**7**	**6**	**8**	**20**

lizards belonging to 21 genera and ten families (Table 3). Gymnophthalmidae was the family with the highest species richness (five, 22.7% of the total number of lizards), followed by Teiidae (four, 18%), Tropiduridae (three, 13.6% each), and Dactyloidae, Alopoglossidae, and Sphaerodactylidae (two each, 9%). Other families were Gekkonidae (represented by one invasive species), Iguanidae, Phyllodactylidae, and Scincidae, with one species each. We registered 28 species of snake belonging to 23 genera from five families (Table 4). Dipsadidae was the richest family, with 16 species (57% of all snake species), followed by Colubridae (five, 17.8%), Boidae (four, 14.3%), and Viperidae with two species (7%). The family Aniliidae was represented by one species.

DISCUSSION

The dominance of Hylidae and Leptodactylidae has been observed in many survey studies in Amazonia (e.g. Bernarde, Albuquerque, Miranda and Turci, 2013; Miranda, Venâncio and Albuquerque, 2014; Fonseca, Silva, Abegg, da Rosa and Bernarde, 2019; Ferreira, Sturaro and Peloso, 2017). Likewise, the high proportion of Dipsadidae snake species is also common in the Amazon region (Frota, Santos-Jr., Chalkidis and Guedes, 2005; Bernarde, Albuquerque, Barros and Turci, 2012; Fraga, Magnusson, Abrahão, Sanaiotti and Lima, 2013a). Still, *Bothrops atrox* was the most abundant snake

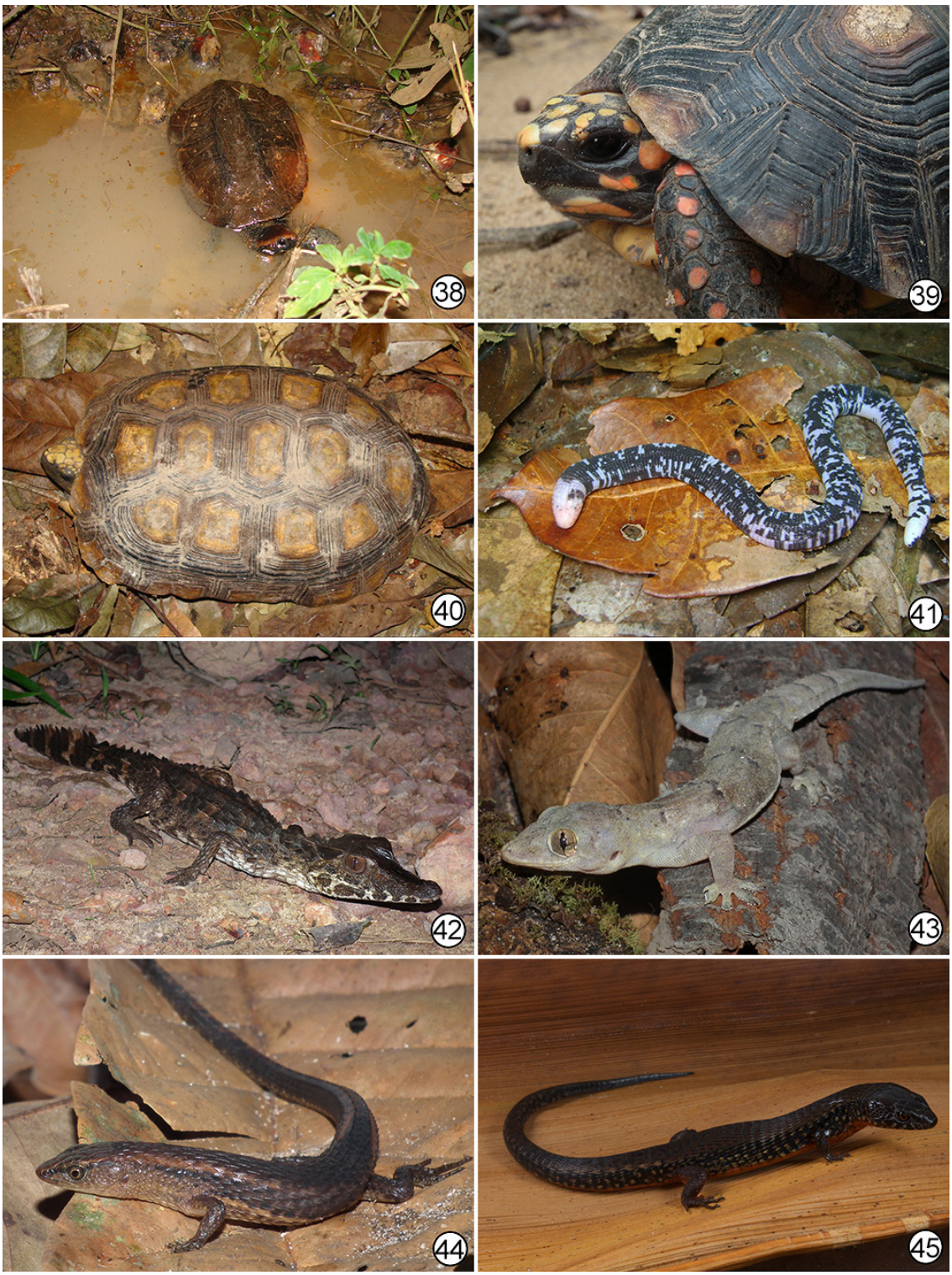

Fig. 38–45. Alligators, turtles, and lizards recorded during fieldwork in Tailândia, Tomé-Açu, and Moju municipalities, Pará state, Brazil. 38: *Platemys platycephala*. 39: *Chelonoidis carbonaria*. 40: *Chelonoidis denticulata*. 41: *Amphisbaena fuliginosa amazonica*. 42: *Paleosuchus trigonatus*. 43: *Hemidactylus mabouia*. 44: *Alopoglossus angulatus*. 45: *Arthrosaura reticulata*.

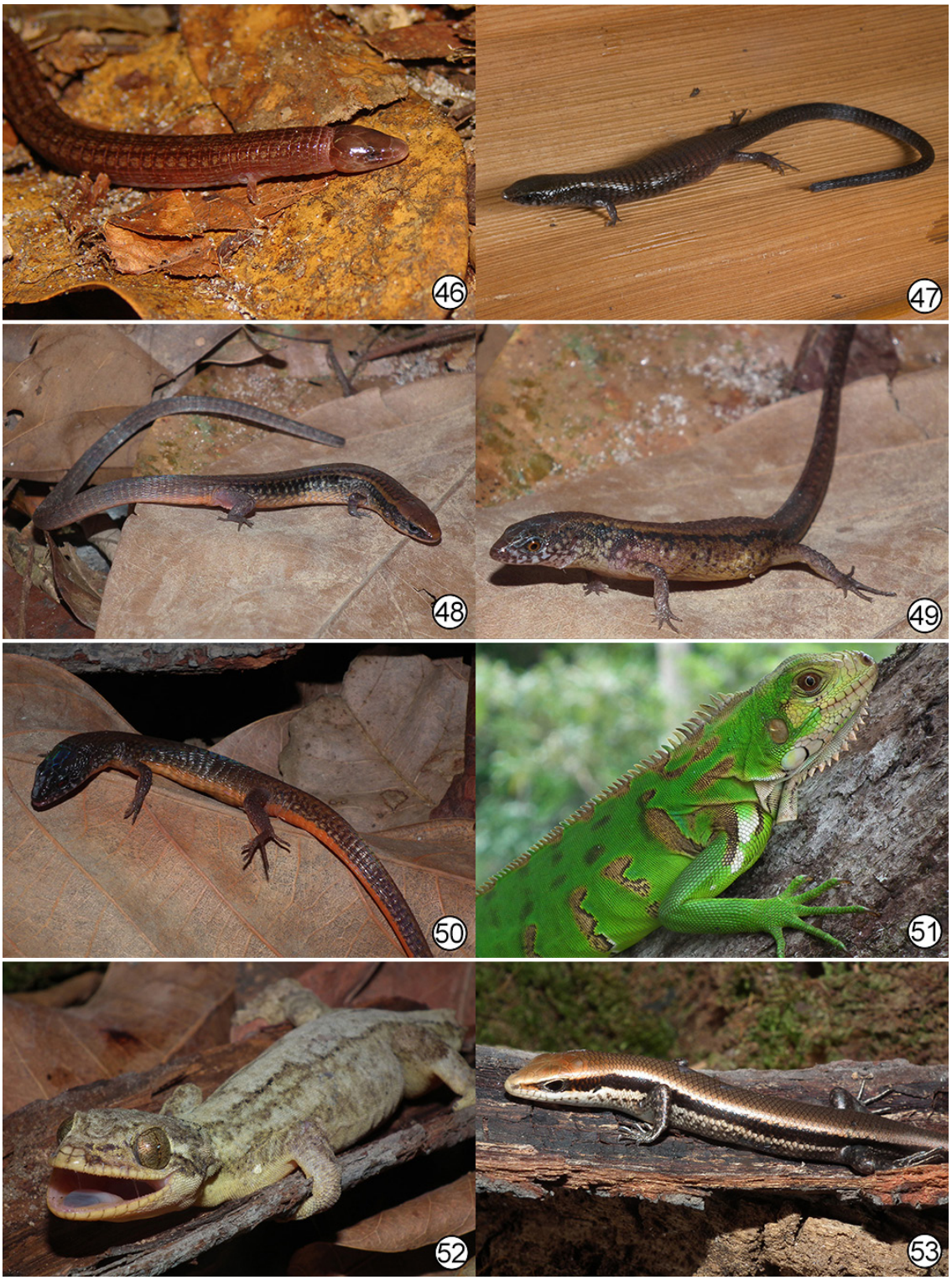

Fig. 46–53. Lizards recorded during fieldwork in Tailândia, Tomé-Açu, and Moju municipalities, Pará state, Brazil. 46: *Bachia flavescens*. 47: *Colobosaura modesta*. 48: *Iphisa elegans elegans*. 49: *Leposoma percarinatum*. 50: *Ptychoglossus brevifrontalis*. 51: *Iguana iguana*. 52: *Thecadactylus rapicauda*. 53: *Copeoglossum nigropunctatum*.

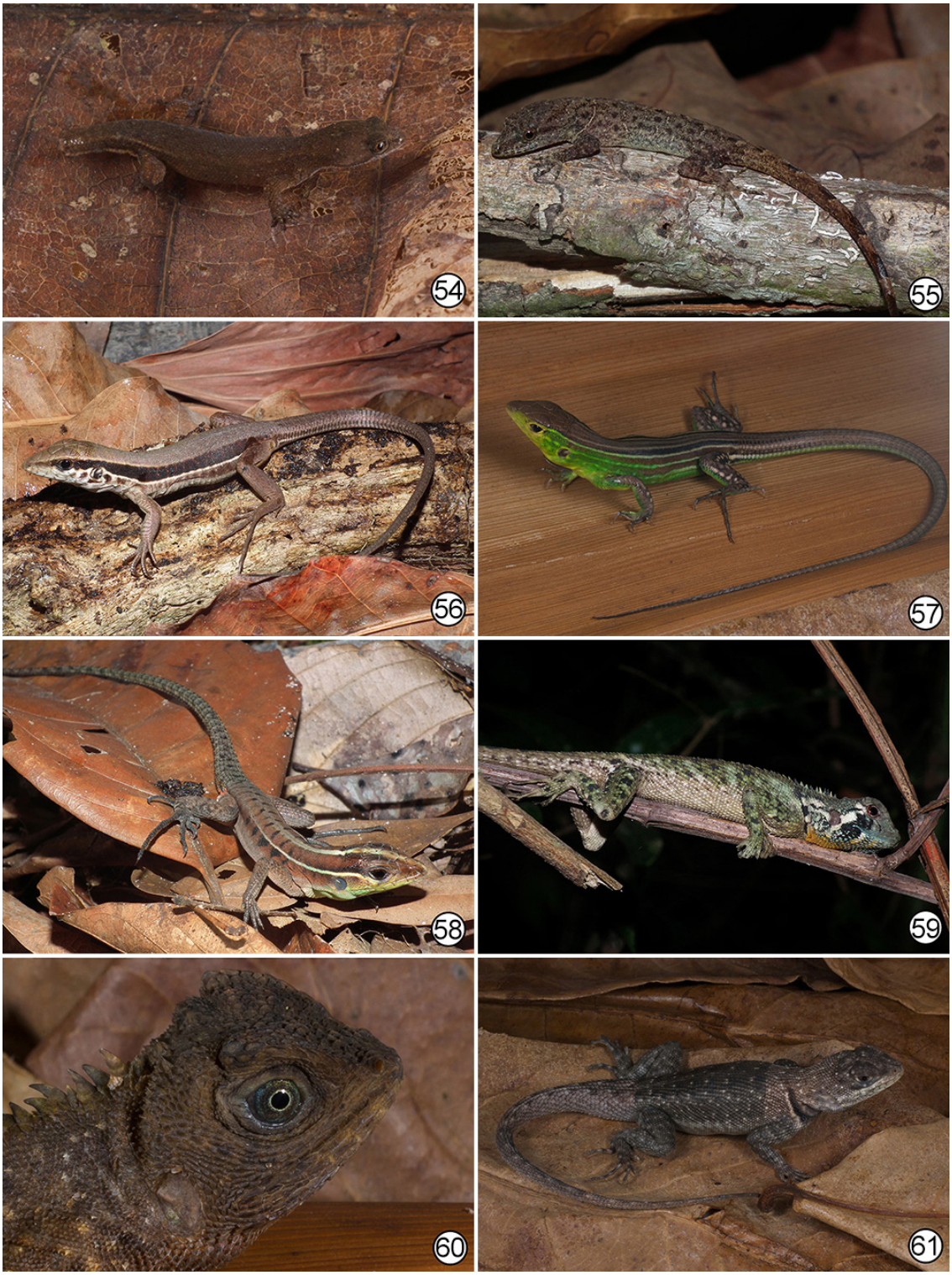

Fig. 54–61. Lizards recorded during fieldwork in Tailândia, Tomé-Açu, and Moju municipalities, Pará state, Brazil. 54: *Chatogekko amazonicus*. 55: *Gonatodes humeralis*. 56: *Ameiva ameiva*. 57: *Cnemidophorus cryptus*. 58: *Kentropyx calcarata*. 59: *Plica umbra*. 60: *Uranoscodon superciliosus*. 61: *Tropidurus oreadicus*.

Fig. 62–69. Snakes recorded during fieldwork in Tailândia, Tomé-Açu, and Moju municipalities, Pará state, Brazil. 62: *Anilius scytale*. 63: *Eunectes murinus*. 64: *Dipsas catesbyi*. 65: *Helicops angulatus*. 66: *Hydrops martii*. 67: *Imantodes cenchoa*. 68: *Oxyrhopus melanogenys*. 69: *Siphlophis cervinus*.

Table 3. Alligators, amphisbaenids, turtles, and lizard species registered in the municipalities of Moju, Tailândia, and Tomé-Açu, Pará state, Brazil. Sites: 1) Agropalma, 2) PPBio, 3) Alvorada Farm, 4) São José Farm, 5) Canaã Farm, 6) Colorado Farm, 7) Acapu Farm, 8) Santo Antônio Farm, and 9) Maísa Farm.

	Taxa	1	2	3	4	5	6	7	8	9
	Chelidae									
1	*Platemys platycephala* (Schneider, 1792)	X								
	Testudinidae									
2	*Chelonoidis carbonaria* (Spix, 1824)									X
3	*Chelonoidis denticulata* (Linnaeus, 1766)	X			X					X
	Alligatoridae									
4	*Paleosuchus palpebrosus* (Cuvier, 1807)	X								
5	*Paleosuchus trigonatus* (Schneider, 1801)									X
	Amphisbaenidae									
6	*Amphisbaena alba* Linnaeus, 1758	X								
7	*Amphisbaena fuliginosa amazonica* Vanzolini, 1951	X								
8	*Amphisbaena mitchelli* Procter, 1923	X								
	Gekkonidae									
9	*Hemidactylus mabouia* (Moreau de Jonnès, 1818)	X	X							X
	Alopoglossidae									
10	*Alopoglossus angulatus* (Linnaeus, 1758)									X
11	*Ptychoglossus brevifrontalis* Boulenger, 1912									X
	Gymnophthalmidae									
12	*Arthrosaura reticulata* (O'Shaughnessy, 1881)		X	X				X		X
13	*Bachia flavescens* (Bonnaterre, 1789)	X								
14	*Colobosaura modesta* (Reinhardt and Luetken, 1862)							X		
15	*Iphisa elegans elegans* Gray, 1851						X			X
16	*Leposoma percarinatum* (Müller, 1923)	X								X
	Iguanidae									
17	*Iguana iguana* (Linnaeus, 1758)	X	X							X
	Phyllodactylidae									
18	*Thecadactylus rapicauda (*Houttuyn, 1782)	X								X
	Dactyloidae									
19	*Norops fuscoauratus* (D'Orbigny, 1837)	X		X	X	X	X	X	X	X
20	*Norops ortonii* (Cope, 1868)					X				
	Scincidae									
21	*Copeoglossum nigropunctatum* (Spix, 1825)	X	X		X			X	X	X
	Sphaerodactylidae									
22	*Chatogekko amazonicus* (Andersson, 1918)	X	X	X						X
23	*Gonatodes humeralis* (Guichenot, 1855)	X	X		X	X				X
	Teiidae									
24	*Ameiva ameiva* (Linnaeus, 1758)	X	X							X
25	*Cnemidophorus cryptus* Cole and Dessauer, 1993	X	X							

Table 3. Cont.

	Taxa	1	2	3	4	5	6	7	8	9
26	*Kentropyx calcarata* Spix, 1825	X	X	X	X	X				X
27	*Tupinambis teguixin* (Linnaeus, 1758)	X	X							X
	Tropiduridae									
28	*Plica umbra ochrocollaris* (Spix, 1825)	X	X	X						X
29	*Tropidurus oreadicus* Rodrigues, 1984		X							
30	*Uranoscodum superciliosus* (Linnaeus, 1758)	X	X							
	Total	**20**	**13**	**5**	**5**	**5**	**2**	**4**	**3**	**19**

species in the region. This species has wide environmental plasticity and is commonly found using various substrates such as leaf litter, marsh, and trees (Cunha and Nascimento, 1983; Martins and Oliveira, 1998; Oliveira and Martins, 2001; Fraga, Magnusson, Abrahão, Sanaiotti and Lima, 2013b). *Bothrops atrox* feeds on both endothermic (e.g. rodents, birds) and ectothermic (e.g. lizards, amphibians) prey, which enables it to thrive on a wide range of environments (Martins and Oliveira, 1998). Such adjustments may be responsible for the high frequency of this species throughout its distribution.

Several amphibians (e.g. species of the genus *Rhinella*, *Boana*, *Dendropsophus*, *Scinax*) and reptiles (e.g. *Ameiva ameiva*, *Iguana iguana*, *Chelonoidis carbonaria*, *Eunectes murinus*, *Helicops* spp.) recorded by us are widely distributed in Amazonia (Caldwell and Araújo, 2005; Ribeiro-Júnior, 2015; Nogueira et al., 2019), and some occur also in other biomes (e.g. *Dendropsophus minutus*, *Leptodactylus fuscus*, *L. mystaceus*, *Helicops angulatus*, *Paleosuchus* spp.) (Rodrigues, 2003; Strüssmann, Ribeiro, Ferreira and Béda, 2007; Haddad et al., 2013). However, some species (e.g. *Rhinella* gr. *margaritifera*, *Adenomera andreae*, *L. mystaceus*, *Iphisa elegans elegans*) represent complexes of cryptic species (Fouquet et al., 2012; Nunes, Fouquet, Curcio, Kok and Rodrigues, 2012). Such results are likely to increase even more the diversity and representativeness of the region and also have direct impact on conservation strategies. Nunes et al. (2012), for example, suggested four new candidate species within *I. e. elegans*, limiting the species range based on molecular methods and hemipenian morphology. Thus, this species, which was considered widely distributed, can now be restricted to the eastern part of Amazonia. Because this region is one of the most threatened in the biome, the conservation status of this candidate species may need to be revaluated. *Iphisa elegans* was described from Pará state by Gray (1851), and later restricted to Belém municipality (Hoogmoed, 1973). Because only two specimens are known from the entire Belém Area of Endemism, the holotype and one additional individual mentioned in literature (Ávila-Pires, 1995; Ribeiro-Júnior and Amaral, 2017), the individuals recorded by us could improve greatly the knowledge on the species conservation and natural history. The same pattern might be found for other species widely distributed in the Amazon, found also in our sampling area.

Six taxa were not identified to species level: *Allobates* sp., *Rhinella* cf. *magnussoni*, *Rhinella* gr. *margaritifera*, *Pristimantis* cf. *moa*, *Boana* aff. *semilineata*, and *Scinax* gr. *ruber*. Several species of *Allobates* have been recently described based on acoustic and molecular data (e.g. Simões, Lima, Magnusson, Hödl and Amezquita, 2008; Simões, Lima and Farias, 2010, Kaefer, Tsuji-Nishikido and Lima, 2012). Still, we did not record calls and were not able to sequence DNA to determine precisely which species were found in our area. According to Lavilla, Caramaschi, Langone, Pombal-Jr. and de Sá (2013), species belonging to the *Rhinella margaritifera* species group are highly polymorphic, making it hard to assign any specimen to a specific species. At least four species from this group (e.g. *R. castaneotica*, *R. magnussoni*, *R. margaritifera*, *R. proboscidea*) may occur in the area, and further investigation using multiple datasets may help unambiguously identify the species in the Belém Area of Endemism. According to a recent study describing four new species of *Pristimantis* for Amazonia, the individuals of this genus recorded here are morphologically similar to *Pristimantis moa* (Oliveira et al., 2020). However, further analyses using

Fig. 70–73. Snakes recorded during fieldwork in Tailândia and Moju municipalities, Pará State, Brazil. 70: *Xenodon rabdocephalus*. 71: *Xenopholis scalaris*. 72: *Bothrops atrox*. 73: *Bothrops brazili*.

bioacoustical and molecular data are needed to correctly identify the population from this region. Some studies have shown that the *Boana semilineata* species group presents several unnamed taxa (candidate species), and the population found in the present study may belong to Candidate S2 (Fouquet et al., 2016; Peloso et al., 2018). The genus *Scinax* is the richest within Hylidae (Nunes and Pombal, 2011), and according to Pombal, Bastos and Haddad (1995), *Scinax* has been taxonomically problematic owing to the large number of species, their morphological conservatism and similarity, and the continuous discovery of undescribed species.

Some species were recorded by only one collection method, underscoring the importance of using multiple methods in herpetofaunal surveys (Gardner et al., 2007; Ribeiro-Júnior et al., 2008). Among the 108 species of amphibians and reptiles recorded in our surveys, 45 were exclusively captured by active search. Fifteen were exclusively captured in pitfall traps, especially small leaf-litter frogs (e.g. *Allobates crombiei*, *Ctenophryne geayi*), and terrestrial/fossorial lizards (e.g. *Alopoglossus angulatus*, *Ameiva ameiva*, *Arthrosaura reticulata*, *Bachia flavescens*, *Iphisa elegans elegans*, *Leposoma percarinatum*, and *Ptychoglossus brevifrontalis*). Pitfall traps are efficient in sampling amphibians and small-sized reptiles, which move on the ground (Ribeiro-Júnior et al., 2011) and present cryptozoic and/or fossorial habits (Enge, 2001), and consequently are rarely sampled by traditional methods of visual search.

Neckel-Oliveira and Hoogmoed (2010) categorized *Bolitoglossa paraensis*, the salamander species listed in this study, as “Data Deficient”, while the Brazilian list of endangered species lists it as "Endangered" (MMA, 2014). In our study, we found 14 individuals of *B. paraensis* in only two forest fragments, and in other regions of the Belém Area of Endemism *B. paraensis* seems to be abundant and highly associated to air humidity and forested environment (Neckel-Oliveira et al., 2011; Correa, Neckel-Oliveira and Rodrigues,

Table 4. Snake species registered in the municipalities of Moju, Tailândia, and Tomé-Açu, Pará State, Brazil. Sites: 1) Agropalma, 2) PPBio, 3) Alvorada Farm, 4) São José Farm, 5) Canaã Farm, 6) Colorado Farm, 7) Acapu Farm, 8) Santo Antônio Farm, and 9) Maísa Farm.

	Taxa	1	2	3	4	5	6	7	8	9
	Aniliidae									
1	*Anilius scytale* (Linnaeus, 1758)		X							
	Boidae									
2	*Boa constrictor* Linnaeus, 1758	X								
3	*Corallus hortulanus* (Linnaeus, 1758)	X								X
4	*Epicrates cenchria* (Linnaeus, 1758)	X								
5	*Eunectes murinus* (Linnaeus, 1758)	X								X
	Colubridae									
6	*Chironius fuscus* (Linnaeus, 1758)	X								
7	*Leptophis ahaetulla* (Linnaeus, 1758)	X								
8	*Mastigodryas boddaerti* (Sentzen, 1796)	X								
9	*Spilotes pullatus* (Linnaeus, 1758)	X								
10	*Tantilla melanocephala* (Linnaeus, 1758)	X								
	Dipsadidae									
11	*Dipsas catesbyi* (Sentzen, 1796)	X								
12	*Dipsas pavonina* Schlegel, 1837	X								
13	*Erythrolamprus reginae* (Amaral, 1935)	X								
14	*Helicops angulatus* (Linnaeus, 1758)	X	X							X
15	*Helicops hagmanni* Roux, 1910	X								
16	*Hydrops martii* (Wagler, 1824)								X	
17	*Imantodes cenchoa* (Linnaeus, 1758)	X		X						
18	*Leptodeira annulata* (Linnaeus, 1758)	X								
19	*Oxyrhopus melanogenys* (Tschudi, 1845)	X								
20	*Oxyrhopus petolarius* Reuss, 1834	X								
21	*Oxyrhopus trigeminus* Duméril, Bibron and Duméril, 1854		X							
22	*Philodryas viridissima* (Linnaeus, 1758)	X								
23	*Pseudoboa coronata* Schneider, 1801	X								
24	*Siphlophis cervinus* (Laurenti, 1768)	X								X
25	*Xenodon rabdocephalus* (Wied, 1824)		X							
26	*Xenopholis scalaris* (Wucherer, 1861)	X								
	Viperidae									
27	*Bothrops atrox* (Linnaeus, 1758)	X								
28	*Bothrops brazili* Hoge, 1954	X								
	Total	**24**	**5**	**1**	**0**	**0**	**0**	**0**	**1**	**4**

2012). Based on this record, we suggest that new populations of *B. paraensis* might be found when sampling effort is increased, contributing to the correct evaluation of the conservation status of this species. Other species observed in this study are listed in the Convention on International Trade in Endangered Species of Wild fauna and flora (CITES). *Adelphobates galactonotus*, *Iguana iguana*, *Tupinambis* spp., *Paleosuchus palpebrosus*, *P. trigonatus*, and *Chelonoidis carbonaria* are in Appendix II (CITES, 2021), which lists species that are not threatened with extinction but that may become, and the trade is closely controlled.

Most of the species observed in our sites are

found in other locations in Amazonia (Azevedo-Ramos and Galatti, 2002; Ávila-Pires, Hoogmoed and Vitt, 2007; Prudente, Magalhães, Menks and Sarmento, 2013; Ribeiro-Júnior, 2018). The Amazon region is composed of different areas of endemism that demand contrasting conservation strategies adapted to local idiosyncrasies (Silva, 2005; Garda et al., 2010; Silva and Garda, 2011). The Belém Area of Endemism is the smallest among the Amazonia areas of endemism, covering 199.211 km^2 in a region known as "arc of deforestation" (Silva *et al*., 2005; Almeida and Vieira, 2010). It encompasses the eastern portion of the lower Tocantins River and shows the highest levels of human occupation and deforestation (with over 65% of its area degraded) while presenting the smallest proportion of protected areas (only 17% under some form of legal protection) (Almeida and Vieira, 2010; Garda et al., 2010). At the same time, this region houses one of the highest species richness in Amazonia (Ribeiro-Júnior and Amaral, 2016b). Still, the knowledge of the region's herpetofaunal diversity is incipient mostly because of the large size of the biome, the small number of universities and herpetologists, low investment, and the rapid colonization in the region in the recent years.

Palm oil plantations are known to harbor a smaller fraction of the biodiversity found in intact forests (15%; Koh, 2008), and the conversion of primary and secondary (logged) forests to palm oil plantations has been proved to severely impact biodiversity (Koh and Wilcove, 2008; Correa, Juen, Rodrigues, Silva-Filho and Santos-Costa, 2015). Currently, several new large-scale investments in palm oil plantations are planned for northeastern Pará state, in the municipalities studied herein. The substitution of native environments and the degradation of the remaining fragments are the main causes of declines and extinctions of most species of amphibians and reptiles (Gibbons et al., 2000; Stuart et al., 2004). It is urgent, therefore, to establish a baseline for local biodiversity maintenance and, hence, provide adequate data to monitor possible biodiversity impacts of land use changes.

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APPENDIX 1.
Specimens collected in the study areas. Numbers 1 to 9 after the colon refer to locations established in Table 1.

Amphibians: Aromobatidae: *Allobates crombiei* (individual not collected – fig. 6); *Allobates* sp. (CHUNB 56273-80: 1); **Bufonidae:** *Amazophrynella xinguensis* (individual not collected); *Rhaebo guttatus* (MPEG 34653: 2); *Rhinella* cf. *magnussoni* (acoustic identification); *Rhinella major* (acoustic identification); *Rhinella* gr. *margaritifera* (AAGARDA 830-2, 834, CHUNB 56286-90: 1, MPEG 34640-52: 2); *Rhinella marina* (AAGARDA 6351: 9, MPEG 34631-9: 2-8); **Ceratophrydae:** *Ceratophrys cornuta* (acoustic identification); **Craugastoridae:** *Pristimantis* cf. *moa* (AAGARDA 6352, 6377, 6381, 6415: 9); **Dendrobatidae:** *Adelphobates galactonotus* (AAGARDA 6370-1, 6374, 6396, 6409, 6410, 6423: 9); **Hylidae:** *Dendropsophus leucophyllatus* (MPEG 34654-8: 2-8); *Dendropsophus microcephalus* (acoustic identification); *Dendropsophus minutus* (AAGARDA 824, CHUNB 56308: 1, MPEG 34659-71: 2); *Dendropsophus nanus* (MPEG 34672-4: 1); *Boana boans* (AAGARDA 6394, 6425-8: 9); *Boana calcarata* (AAGARDA 6429-31: 9); *Boana cinerascens* (AAGARDA 903-8, CHUNB 56298-308: 1, AAGARDA 6356: 9); *Boana* aff. *semilineata* (acoustic identification); *Boana multifasciata* (AAGARDA 6355, 6401-2, 6432: 9, MPEG 34675-81: 1-6, 8); *Osteocephalus leprieurii* (acoustic identification); *Osteocephalus oophagus* (AAGARDA 6359, 6420: 9, MPEG 34682: 2); *Osteocephalus taurinus* (acoustic identification); *Phyllomedusa bicolor* (acoustic identification); *Phyllomedusa tomopterna* (acoustic identification); *Phyllomedusa vaillantii* (AAGARDA 6354, 6360, 6378: 9); *Pithecopus hypochrondrialis* (MPEG 34683-96: 1, 2); *Scinax boesemani* (acoustic identification); *Scinax fuscovarius* (acoustic identification); *Scinax nebulosus* (AAGARDA 6357-8, 6393: 1); *Scinax rostratus* (MPEG 34697-8: 1, 2); *Scinax* gr. *ruber* (AAGARDA 829, CHUNB 56293: 1, MPEG 34699-703: 1); *Trachycephalus resinifictrix* (acoustic identification); *Trachycephalus typhonius* (AAGARDA 6442: 9); **Leptodactylidae:** *Adenomera andreae* (CHUNB 56311-13, 56319-22: 1, 2); *Adenomera hylaeadactyla* (AAGARDA 857, 871, 888, 902: 1, AAGARDA 6367, 6372, 6389-90, 6421-2: 9, MPEG 34705-7: 1); *Leptodactylus fuscus* (MPEG 34708-14: 1, 2); *Leptodactylus knudseni* (individual not collected); *Leptodactylus macrosternum* (AAGARDA 6392: 9, MPEG 34715-27: 1-8); *Leptodactylus mystaceus* (MPEG 34730-6, CHUNB 56292: 1, 2); *Leptodactylus paraensis* (AAGARDA 833, 838, 842, MPEG 34738-42, CHUNB 5631: 1, 2); *Leptodactylus pentadactylus* (AAGARDA 872: 1, AAGARDA 6368, 6414: 9); *Leptodactylus petersii* (AAGARDA 895, 898: 1); *Leptodactylus rhodomystax* (MPEG 34646-9: 2); *Physalaemus ephippifer* (AAGARDA 835-7, 839, CHUNB 56294-6, 56304-5: 1, AAGARDA 6365, 6383, 6384: 9, MPEG 34750-65: 2-5, 6-8); *Pseudopaludicola mystacalis* (acoustic identification); **Microhylidae:** *Ctenophryne geayi* (MPEG 32138-69: 1); **Pipidae:** *Pipa pipa* (individual not collected); **Plethodontidae:** *Bolitoglossa paraensis* (individual not collected – fig. 37); **Typhlonectidae:** *Typhlonectes compressicauda* (individual not collected).

Reptiles: Chelidae: *Platemys platycephala* (AAGARDA 862, CHUNB 56254: 1); **Testudinidae:** *Chelonoidis carbonaria* (individual not collected – fig. 39); *Chelonoidis denticulata* (individual not collected – fig. 40); **Alligatoridae:** *Paleoshuchus palpebrosus* (individual not collected); *Paleosuchus trigonatus* (individual not collected – fig. 42); **Amphisbaenidae:** *Amphisbaena alba* (individual not collected); *Amphisbaena fuliginosa amazonica* (individual not collected – fig. 41); *Amphisbaena mitchelli* (individual not collected); **Gekkonidae:** *Hemidactylus mabouia* (AAGARDA 6353: 9); **Gymnophthalmidae:** *Alopoglossus angulatus* (AAGARDA 6416: 9); *Arthrosaura reticulata* (MPEG 30068: 2); *Bachia flavescens* (AAGARDA 821, 899, CHUNB 56268-9: 1); *Colobosaura modesta* (individuall not collected – fig. 47); *Iphisa elegans elegans* (AAGARDA 6387, 6398-9, 6406, 6440: 9); *Leposoma percarinatum* (AAGARDA 847, CHUNB 56272: 1, AAGARDA 6385, 6400, 6404: 9); *Ptychoglossus brevifontralis* (AAGARDA 6441: 9); **Iguanidae:** *Iguana iguana* (AAGARDA 6395: 9); **Phyllodactylidae:** *Thecadactylus rapicauda* (AAGARDA 6382, 6433, 6438-9: 9); **Dactyloidae:** *Norops fuscoauratus* (AAGARDA 877, 887: 1, 6411-2, 6419, 6436: 9, CHUNB 56265-7: 3); *Norops ortonii* (AAGARDA 860: 5); **Scincidae:** *Copeoglossum nigropunctatum* (AAGARDA 870, CHUNB 56262: 1, AAGARDA 6391: 9, MPEG 30066, 30117: 2, 4, 7); **Sphaerodactylidae:** *Chatogekko amazonicus* (AAGARDA 822, 856-6, CHUNB 56273-80: 1, AAGARDA 6362, 6364, 6403, 6413: 9, MPEG 30059-60: 2, 3); *Gonatodes humeralis* (AAGARDA 853, 867-8, CHUNB 56263-4: 1, AAGARDA 6366, 6369, 6435: 9, MPEG 30053-8: 2, 4, 5); **Teiidae:** *Ameiva ameiva* (AAGARDA 6373, 6417, 6434: 9); *Cnemidophorus cryptus* (AAGARDA 883, CHUNB 56271: 1, MPEG 30088-116 2); *Kentropyx calcarata* (AAGARDA 848, 864-5, CHUNB 56258-61: 1, AAGARDA 6363, 6407-8, 6418, 6424: 9, MPEG 30050-2: 2-5); *Tupinambis teguixin* (individual not collected); **Tropiduridae:** *Plica umbra ochrocollaris* (AAGARDA 882, 901: 1, AAGARDA 6386, 6437: 9); *Tropidurus oeradicus* (MPEG 30067: 2); *Uranoscodum superciliosus* (AAGARDA 879, CHUNB 56255: 1, MPEG 30064-5, 30070: 2).

Snakes: Aniliidae: *Anilius scytale* (MPEG 25155: 2); **Boidae:** *Boa constrictor* (MPEG 25151: 2); *Corallus*

hortulanus (AAGARDA 6380: 9); *Epicrates cenchria* (individual not collected); *Eunectes murinus* (individual not collected – fig. 63); **Colubridae:** *Chironius fuscus* (AAGARDA 6361: 1); *Leptophis ahaetulla* (individual not collected); *Mastigodryas boddaerti* (CHUNB 56246: 1); *Spilotes pullatus* (individual not collected); *Tantilla melanocephala* (AAGARDA 826-7, CHUNB 56250-1: 1); **Dipsadidae:** *Dipsas catesbyi* (CHUNB 56253: 1); *Dipsas pavonina* (individual not collected); *Erythrolamprus reginae* (CHUNB 56248: 1); *Helicops angulatus* (AAGARDA 6376: 9); *Helicops hagmanni* (AAGARDA 823, CHUNB 56244: 1); *Hydrops martii* (individual not collected); *Imantodes cenchoa* (AAGARDA 825, CHUNB 56252: 1); *Leptodeira annulata* (individual not collected); *Oxyrhopus melanogenys* (individual not collected); *Oxyrhopus petolaris* (individual not collected); *Oxyrhopus trigeminus* (individual not collected); *Philodryas viridissima* (individual not collected); *Pseudoboa coronata* (individual not collected); *Siphlophis cervinus* (AAGARDA 6375: 9); *Xenodon rabdocephalus* (MPEG 25152: 2); *Xenopholis scalaris* (AAGARDA 863, CHUNB 56249: 1); **Viperidae:** *Bothrops atrox* (AAGARDA 896, 900, CHUNB 56245, 56247: 1); *Bothrops brazili* (individual not collected – fig. 73).

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