

Herpetofauna of an urban environmental protection area in an Amazon forest remnant of Amapá state, northern Brazil

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ABSTRACT

The herpetofauna of Amazonia biome is one of the richest in the world. However, there is a lack of information on its richness and distribution. Here we provide a list of the herpetofauna from the Environmental Protection Area of Lagoa dos Índios, state of Amapá, Brazil, in the northern Amazon Forest. Sampling effort was conducted by active search in three distinct transects from January to May 2018 (rainy season) and August to December 2019 (drought season). We recorded 46 species composing the local herpetofauna, being 18 amphibians and 28 reptiles. *Scinax ruber*, *Gonatodes humeralis* and *Helicops angulatus* were the most abundant species. Regarding the conservation status, two species are categorized as Data Deficient, (*Lysapsus bolivianus* and *Eunectes deschauenseei*), and one as Vulnerable (*Podocnemis unifilis*) in the Red List of the International Union for Conservation of Nature. *Podocnemis unifilis* is also considered *Near Threatened* in the Brazilian Red List of Endangered Species. Our results suggest that local biodiversity is still underestimated and, if expanded, could increase the species richness in the area. This study represents preliminary trends and raise further questions concerning the herpetofauna assemblage of Eastern Brazilian Amazonia.

Key words: Amphibians; Herpetological surveys; Reptiles.

RESUMEN

El bioma de la herpetofauna de la Amazonia es uno de los más ricos del mundo. Sin embargo, falta información sobre su riqueza y distribución. Aquí proporcionamos una lista de la herpetofauna del Área de Protección Ambiental de Lagoa dos Índios, estado de Amapá, Brasil, en el norte de la Selva Amazónica. El esfuerzo de muestreo se realizó mediante búsqueda activa en tres transectos distintos de enero a mayo de 2018 (temporada de lluvias) y de agosto a diciembre de 2019 (temporada de sequía). Registramos 46 especies que componen la herpetofauna local, siendo 18 anfibios y 28 reptiles. *Scinax ruber*, *Gonatodes humeralis* y *Helicops angulatus* fueron las especies más abundantes. En cuanto al estado de conservación, dos especies están categorizadas como Datos deficientes en fecha, (*Lysapsus bolivianus* y *Eunectes deschauenseei*), y una como Vulnerable (*Podocnemis unifilis*) en la Lista Roja de la Unión Internacional para la Conservación de la Naturaleza. *Podocnemis unifilis* también se considera Casi Amenazada en la Lista Roja Brasileña de Especies Amenazadas. Nuestros resultados sugieren que la biodiversidad local todavía se subestima y, si se amplía, podría aumentar la riqueza de especies en el área. Este estudio representa tendencias preliminares y plantea más preguntas sobre el conjunto de herpetofauna de la Amazonia brasileña oriental.

Palabras claves: Anfibios; Inventario; Reptiles.

Introduction

The territory of the state of Amapá, in the Brazilian Amazon Forest, is mostly covered by protected areas harboring a mosaic of conservation units and indigenous lands (Mustin *et al.*, 2017). The State is known

by harboring a rich biodiversity, and some herpetofauna surveys have corroborated this statement (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; Prudente *et al.*, 2020; Costa-Campos *et al.*, 2021).

The herpetofauna of the northern region of Amapá state remained unknown due to the lacking of data on the natural history and geographic distribution of several taxa, which led to a false idea of a low species richness. This scenario has changed, and several inventories were conducted in in order to better describe the herpetofauna, providing new occurrences and describing new species, especially in the eastern Amazon (Fouquet *et al.*, 2016; Ribeiro-Júnior *et al.*, 2016; Costa and Bérnils, 2018; Taucce *et al.*, 2020; Fouquet *et al.*, 2021).

In this study, we present the species of amphibians and reptiles that compose the herpetofauna from the Environmental Protection Area of Lagoa dos Índios, subject to human pressure in the Amazonia biome, northern region of Brazil, and provide the conservation status.

Materials and methods

Study area— Our study was conducted in the Environmental Protection Area (PAs) of Lagoa dos Índios (0.0288°N, 51.0978°W), located on the banks of the Duca Serra Highway, municipality of Macapá, state of Amapá, Brazil (Figure 1). This PAs has an area of 11 km and connects to the Fortaleza Hydrographic Basin, an important tributary to the Amazon River (Tavares-Dias *et al.*, 2013), and it is representative of the “*terra firme*” (upland forest) and flooded forest.

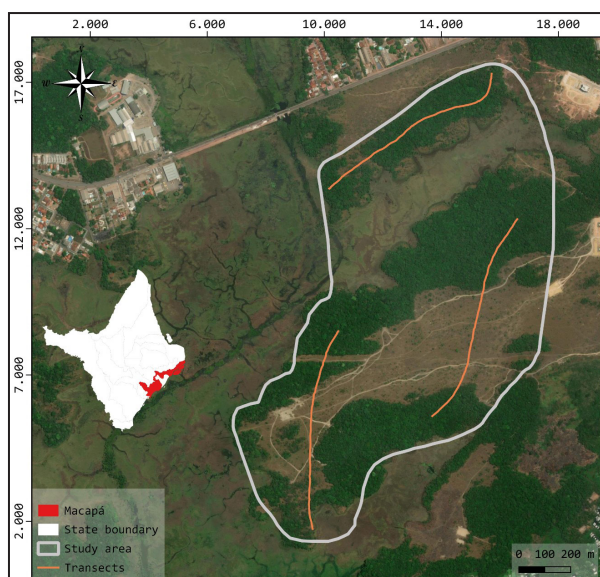


Figure 1. Map showing the geographic location of the Environmental Protection Area of Lagoa dos Índios, in southeast portion of Macapá municipality, Amapá state, northern region of Brazil.

The climate is Am according to the Köppen-Geiger system (tropical monsoon, without a dry season) and the mean annual rainfall is nearly 1,885 mm and average is 27 °C (Peel *et al.*, 2007). The PAs Lagoa dos Índios history presents environmental conflicts arising from urbanization process and high degree of anthropogenic disturbance (Vargas and Bastos, 2013).

Data collection—We sampled the herpetofauna in two different periods, from January to May 2018 (rainy season) and August to December 2019 (drought season), by using active search (Heyer *et al.*, 1994). Sampling effort was conducted in three distinct transects of 1.5 km distant by at least 1 km by a team made up of four collectors. Our sampling effort comprises about 1.020 hours of observation, of which 720 h during the night (6 pm – 9 pm) and 300 h during the day (8 am – 11 am).

The collected specimens were killed using lidocaine, fixed in 10% formaldehyde, and preserved in 70% ethanol (Pisani, 1973) and housed in the Herpetological Collection of the Universidade Federal do Amapá (CECC, Appendix 1), except for a few species of reptiles (the turtles *Chelonoidis carbonarius* and *Podocnemis unifilis*, the lizards *Iguana iguana iguana*, the snakes *Boa constrictor constrictor*, *Eunectes murinus*, *Hydrodynastes gigas*, and the crocodylian *Caiman crocodilus crocodilus*) that were too large for preservation and storage.

The zoological nomenclature adopted herein follows Segalla *et al.* (2021) for amphibians, and Costa *et al.* (2021) for reptiles. We assessed the conservation status of individuals identified to species level using the International Union for Conservation of Nature red list web interface (IUCN, 2022), and Brazilian Red List of Endangered Species (ICMBio, 2018). Only *Hemidactylus mabouia* was not evaluated since it an exotic species.

Analyzes—We perform a rarefaction curves for amphibians, lizards, snakes and all the herpetofauna combined, based on individuals collected over time (Gotelli and Colwell, 2001), through 1,000 randomizations of an abundance matrix where each column represents a species and each row represents a sample. We used species richness estimator Jackknife1 to determine the expected richness for amphibians, lizards, snakes and all the herpetofauna combined. We did not build chelonian or crocodylian curves because these taxa were only rarely present. Both rarefaction curves and the Jackknife 1 were done

performing using the software EstimateS v.9.1.0 (Colwell, 2013). The occurrence of the registered species was evaluated by the constancy index of occurrence (Dajoz, 2005), classified as: abundant (present in > 50% of samples), common (present in 25 to 50% of samples) or rare (present in < 25% of samples).

Results

We recorded a total of 46 species composing the local herpetofauna, being 18 amphibians and 28 reptiles

(Table 1; Figure 2). *Scinax ruber*, *Gonatodes humeralis* and *Helicops angulatus* are the most abundant species. According to constancy index of occurrence, the number of abundant species recorded was higher and represented 45.7% of the community (n = 21; >50%), followed by rare species (n = 15; 32.6%; >25% <50%) and common species (n = 10; 21.7%; <25%). Of the 46 species listed, none are considered endemic to the Amazon Forest biome.

According to the Red List of the International Union for Conservation of Nature (IUCN, 2022)

Table 1. List of amphibians and reptiles species, number of specimens, constancy index and the conservation status according to the Red List of the International Union for Conservation of Nature (IUCN) and Brazilian Red List of Endangered Species (ICMBio) recorded from January to May 2018 (rainy season) and August to December 2019 (wet season), in the Environmental Protection Area of Lagoa dos Índios, Macapá municipality, Amapá state, Brazil. NL = not listed; LC = Least Concern; DD = Date Deficient; VU = Vulnerable; NT = Near Threatened.

Family	Species	Number of specimens	Constancy index	IUCN	ICMBio
ANURA					
Bufonidae					
	<i>Rhinella major</i> (Muller & Helmich, 1936)	7	Abundant	NL	LC
	<i>Rhinella marina</i> (Linnaeus, 1758)	9	Abundant	LC	LC
Hylidae					
	<i>Boana punctata</i> (Schneider, 1799)	5	Common	LC	LC
	<i>Boana raniceps</i> (Cope, 1862)	9	Abundant	LC	LC
	<i>Dendropsophus leucophyllatus</i> (Beireis, 1783)	7	Abundant	LC	LC
	<i>Dendropsophus walfordi</i> (Bokermann, 1962)	4	Common	LC	LC
	<i>Lysapsus bolivianus</i> Gallardo, 1961	6	Abundant	DD	NL
	<i>Pseudis paradoxa</i> (Linnaeus, 1758)	4	Common	LC	LC
	<i>Scinax ruber</i> (Laurenti, 1768)	10	Abundant	LC	LC
	<i>Sphaenorhynchus lacteus</i> (Daudin, 1800)	7	Abundant	LC	LC
	<i>Trachycephalus typhonius</i> (Linnaeus, 1758)	4	Common	LC	LC
Leptodactylidae					
	<i>Adenomera hylaedactyla</i> (Cope, 1868)	9	Abundant	LC	LC
	<i>Leptodactylus macrosternum</i> Miranda-Ribeiro, 1926	2	Rare	LC	LC
	<i>Leptodactylus pentadactylus</i> (Laurenti, 1768)	4	Common	LC	LC
	<i>Leptodactylus podicipinus</i> (Cope, 1862)	9	Abundant	LC	LC
Microhylidae					
	<i>Elachistocleis helianneae</i> Caramaschi, 2010	3	Rare	LC	LC
Pipidae					
	<i>Pipa pipa</i> (Linnaeus, 1758)	4	Common	LC	LC
GYMNOPHIONA					
Typhlonectidae					
	<i>Typhlonectes compressicauda</i> (Duméril & Bibron, 1841)	2	Rare	LC	LC

TESTUDINES

Testudinidae

Chelonoidis carbonarius (Spix, 1824) 1 Rare NL LC

Podocnemididae

Podocnemis unifilis Troschel, 1848 4 Common VU NT

CROCODYLIA

Alligatoridae

Caiman crocodilus crocodilus (Linnaeus, 1758) 2 Rare LC LC

SQUAMATA

Gekkonidae

Hemidactylus mabouia (Moreau de Jonnés, 1818) 8 Abundant --- ---

Sphaerodactylidae

Gonatodes humeralis (Guichenot, 1855) 9 Abundant LC LC

Mabuyidae

Copeoglossum nigropunctatum (Spix, 1825) 6 Abundant LC LC

Iguanidae

Iguana iguana iguana (Linnaeus, 1758) 6 Abundant LC LC

Tropiduridae

Tropidurus hispidus (Spix, 1825) 6 Abundant LC LC

Gymnophthalmidae

Arthrosaura kockii (Lidth de Jeude, 1904) 2 Rare LC LC

Teiidae

Ameiva ameiva ameiva (Linnaeus, 1758) 7 Abundant LC LC

Cnemidophorus cryptus Cole & Dessauer, 1993 6 Abundant NL LC

Aniliidae

Anilius scytale (Linnaeus, 1758) 3 Common LC LC

Boidae

Boa constrictor constrictor Linnaeus, 1758 1 Rare NL LC

Eunectes deschauenseei Dunn & Conant, 1936 3 Common DD LC

Eunectes murinus (Linnaeus, 1758) 6 Abundant NL LC

Colubridae

Chironius carinatus (Linnaeus, 1758) 1 Rare LC LC

Dipsadidae

Imantodes cenchoa (Linnaeus, 1758) 1 Rare LC LC

Hydrodynastes gigas (Duméril, Bibron & Duméril, 1854) 1 Rare NL LC

Helicops angulatus (Linnaeus, 1758) 8 Abundant LC LC

Helicops leopardinus (Schlegel, 1837) 6 Abundant LC LC

Helicops trivittatus (Gray, 1849) 7 Abundant LC LC

<i>Pseudoeryx plicatilis plicatilis</i> (Linnaeus, 1758)	1	Rare	LC	LC
<i>Oxyrhopus melanogenys melanogenys</i> (Tschudi, 1845)	1	Rare	LC	LC
<i>Thamnodynastes pallidus</i> (Linnaeus, 1758)	5	Common	LC	LC
<i>Erythrolamprus cobella</i> (Linnaeus, 1758)	1	Rare	LC	LC
<i>Erythrolamprus reginae semilineatus</i> (Wagler in Spix, 1824)	1	Rare	LC	LC
<i>Lygophis lineatus</i> (Linnaeus, 1758)	1	Rare	LC	LC
Viperidae				
<i>Bothrops atrox</i> (Linnaeus, 1758)	7	Abundant	NL	LC

the species from PAs Lagoa dos Índios were classified into four categories: Least Concern (n = 35), Non Evaluated (n = 7), Data Deficient (n = 2) and Vulnerable (n = 1). *Lysapsus bolivianus* (anuran amphibian) and *Eunectes deschauenseei* (snake) are classified Data Deficient and *Podocnemis unifilis* (turtle) is considered Vulnerable. According to the Brazilian Red List of Endangered Species (ICMBio, 2018), most of the species found in the Environmental Protection Area of Lagoa dos Índios are Least Concern (n = 43; 93.5%). *Podocnemis unifilis* is considered NT (Near Threatened).

Among the amphibians, the family Hylidae presented the highest species richness (nine species, 52.9%), followed by Leptodactylidae (four species, 23.5%) and Bufonidae (two species, 11.8%). Gymnophiona was represented by one species (Typhlonectidae). Among the reptiles, Dipsadidae (12 species, 48%) and Boidae (three species, 12%) were the richest families among the squamates.

Regarding the sampling effort, the accumulation curve began to reach an asymptote at the end of the study for amphibians and lizards (Figure 3). For snakes and herpetofauna (amphibian and reptile species), the accumulation curve do not reached the asymptote at the end of the sampling effort.

Discussion

The 46 species (18 amphibians and 28 reptiles) recorded in the present study corresponded to 14.5 % of the 124 amphibians species (Lima, 2017) and 17.4 % of the 161 reptiles species (Costa and Bérnils, 2018) known for the country. The herpetofauna richness at Environmental Protection Area of Lagoa dos Índios is relatively low when compared to the other Amazonian sites (23 lizards and amphisbaenians species in Campos *et al.*, 2015; 28 amphibians species

in Lima *et al.*, 2017; 50 anurans and reptiles species in Pedroso-Santos *et al.*, 2019; 95 reptiles species in Prudente *et al.*, 2020; and 57 reptiles species in Costa-Campos *et al.*, 2021). Similar results were reported in the Amazonian, where species richness decreased with increasing intensity of human impact (Menin *et al.*, 2019; Peixoto *et al.*, 2019; Almeida-Corrêa *et al.*, 2020). Perhaps habitat loss, urbanization and forest fragmentation comprise primary threats to amphibians and reptiles populations in the Neotropics (Stuart *et al.*, 2004; Verdade *et al.*, 2012).

The high reptile richness supports the hypothesis that these group of animals are not as sensitive to fragmentation as other taxa (e.g. anurans), and that some species can thrive in partially disturbed habitats (Kurz *et al.*, 2013; Bitar *et al.*, 2014). Additionally, we captured a relatively high number of snake species, but few individuals (max three individuals) compared to lizards, which may also account for the steep rarefaction curve.

The snakes' species *Boa constrictor constrictor*, *Chironius carinatus*, *Imantodes cenchoa*, *Hydrodynastes gigas*, *Pseudoeryx plicatilis plicatilis*, *Oxyrhopus melanogenys melanogenys*, *Erythrolamprus cobella*, *E. reginae semilineatus* and *Lygophis lineatus* were recorded only in one sample and according index of constancy of occurrence were considered rare (<25%). Snakes are difficult to sample since they used to appear in low densities (compared to lizards, in this study), most species are of cryptic coloration, and have secretive habitats (Martins and Oliveira, 1998; Santos-Costa *et al.*, 2015), and the detection is even more difficult in tropical forests (Fraga *et al.*, 2014; Frazão *et al.*, 2020).

The prevalence of Hylidae and Leptodactylidae families in relation to the other anuran families is a similar result as in other locations of the Amazon region (Lima *et al.*, 2017; Silva e Silva and Costa-

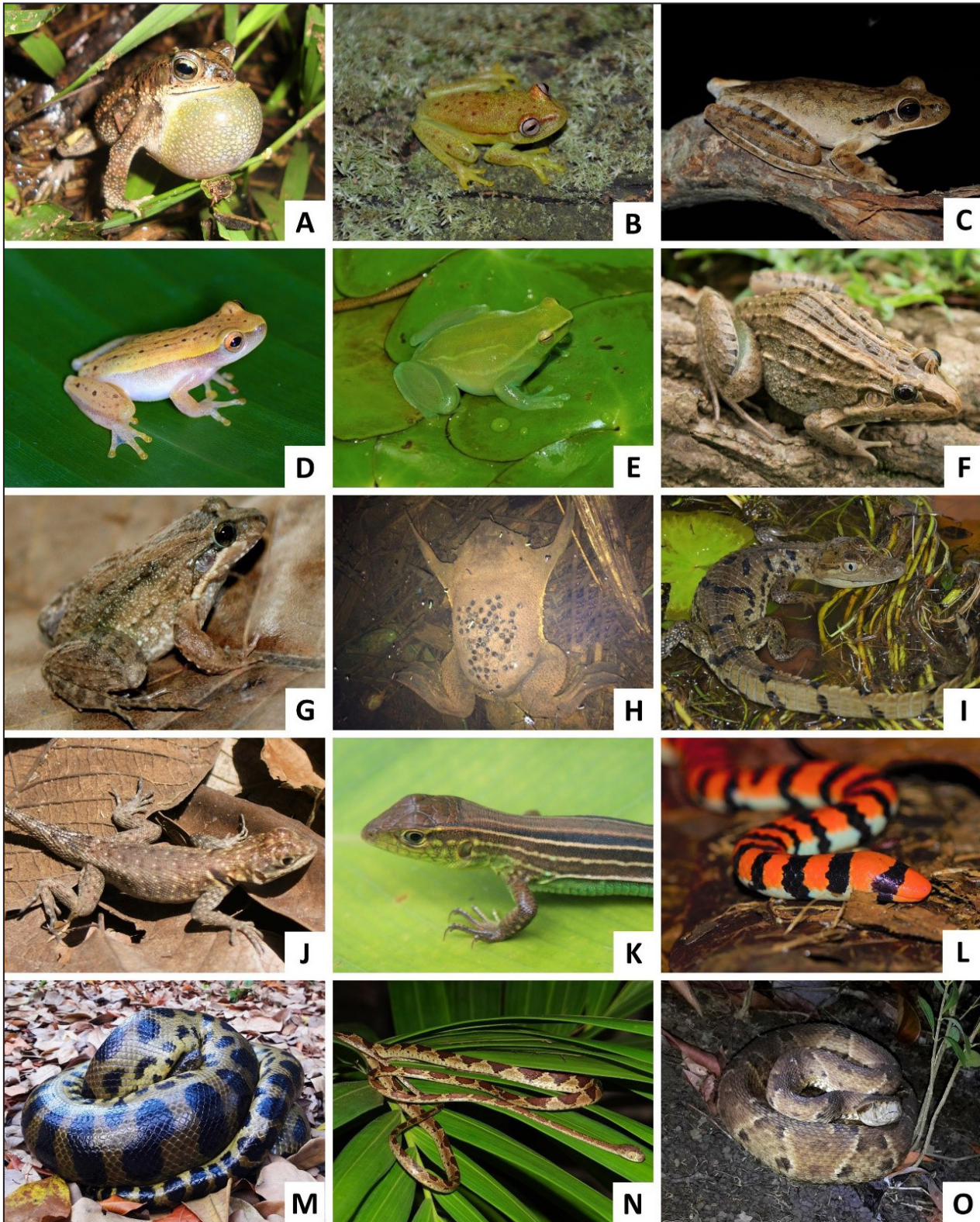


Figure 2. Some species of amphibians and reptiles from the Environmental Protection Area of Lagoa dos Índios, Macapá municipality, Amapá state, northern Brazil. (A) *Rhinella major*; (B) *Boana punctata*; (C) *B. raniceps*; (D) *Dendropsophus walfordi*; (E) *Sphaenorhynchus lacteus*; (F) *Leptodactylus macrosternum*; (G) *L. podicipinus*; (H) *Pipa pipa*; (I) *Caiman crocodilus crocodilus*; (J) *Tropidurus hispidus*; (K) *Cnemidophorus cryptus*; (L) *Anilius scytale*; (M) *Eunectes deschauenseei*; (N) *Imantodes cenchoa*; (O) *Bothrops atrox*.

Campos, 2018; Pedroso-Santos *et al.*, 2019). For lizards, Teiidae family presented greater richness.

Species of this family (e.g. *Ameiva ameiva* and *Cnemidophorus cryptus*) seem to benefit from the

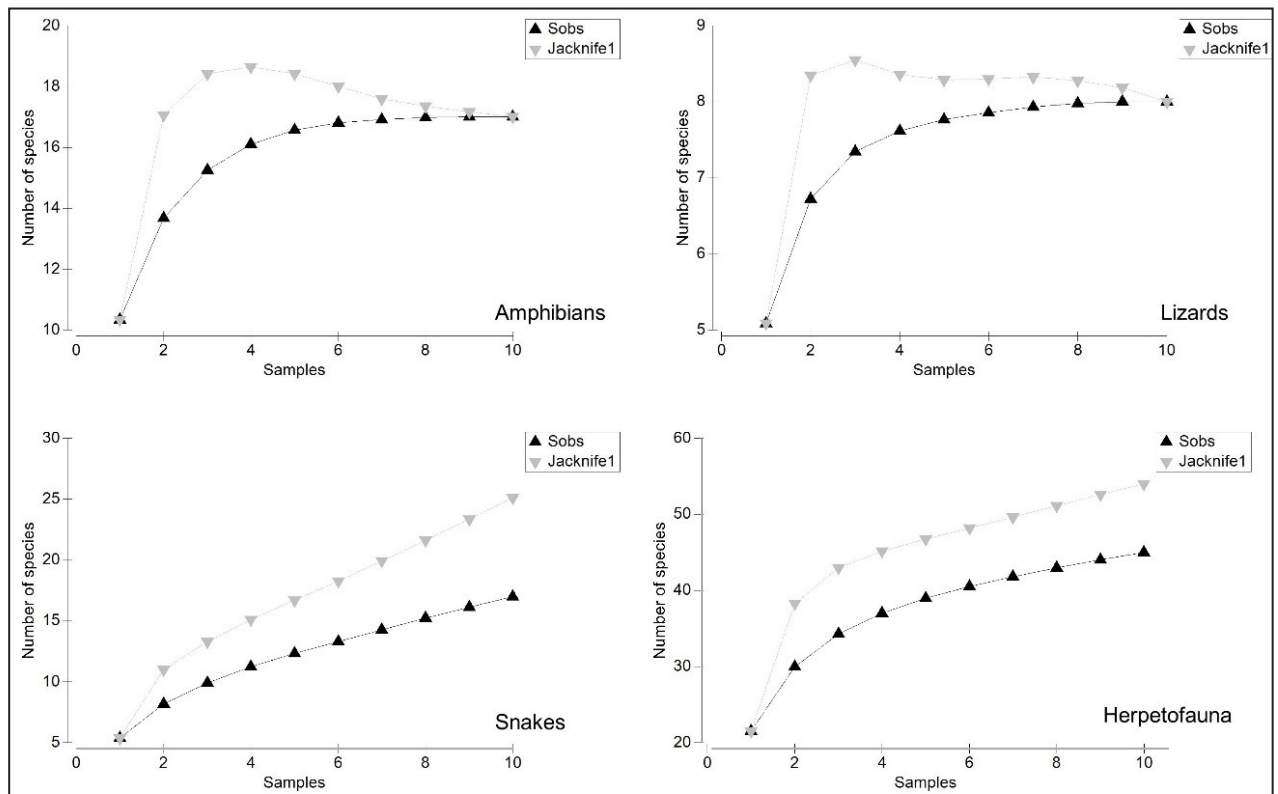


Figure 3. Accumulation and rarefaction curve for (A) amphibians, (B) lizards, (C) snakes and (D) pooled herpetofauna coupled with a species richness estimator Jackknife 1, recorded from January to May 2018 (rainy season) and August to December 2019 (wet season) in the Environmental Protection Area of Lagoa dos Índios, Macapá municipality, Amapá state, northern Brazil.

effects of fragmentation and urbanization (Andrade *et al.*, 2019), responding positively to fragmentation showing a marked increase in abundance (Sartorius *et al.*, 1999). Dipsadidae was the most representative family of snakes, as also reported in other studies (Debien *et al.*, 2019; Frazão *et al.*, 2020), which was expected since this is the richest family of reptile species in Brazil (Costa and Bérnils, 2018; Nogueira *et al.*, 2019).

The herpetofauna of the Environmental Protection Area of Lagoa dos Índios is composed predominantly of species widely distributed in Amazonia biome. Our results represent preliminary trends and raise further questions concerning the assemblage of Eastern Brazilian Amazonia.

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APPENDIX 1

Voucher specimens of amphibians and reptiles from the Environmental Protection Area of Lagoa dos Índios, in southeast portion of Amapá state, Macapá municipality, northern region of Brazil.

AMPHIBIANS: Anura: *Rhinella major* (0030); *Rhinella marina* (0122); *Boana punctata* (0498); *Boana raniceps* (0451); *Dendropsophus leucophyllatus* (0086); *Dendropsophus walfordi* (2345); *Lysapsus bolivianus* (0449); *Pseudis paradoxa* (2757); *Scinax ruber* (2784); *Sphaenorhynchus lacteus* (0113); *Trachycephalus typhonius* (2343); *Adenomera hylaedactyla* (0557); *Leptodactylus macrosternum* (2187); *Leptodactylus pentadactylus* (0119); *Leptodactylus podicipinus* (0521); *Elachistocleis helianneae* (0543); *Pipa pipa* (2391); Gymnophiona: *Typhlonectes compressicauda* (2973).
REPTILES: Squamata: *Hemidactylus mabouia* (0899); *Gonatodes humeralis* (2700); *Copeoglossum nigropunctatum* (1061); *Tropidurus hispidus* (0872); *Arthrosaura kockii* (1013); *Ameiva ameiva ameiva* (1076); *Cnemidophorus cryptus* (1062); *Anilius scytale* (2974); *Eunectes deschauenseei* (2892); *Chironius carinatus* (2975); *Imantodes cenchoa* (2976); *Helicops angulatus* (1040); *Helicops leopardinus* (1363); *Helicops trivittatus* (1194); *Pseudoeryx plicatilis plicatilis* (2977); *Oxyrhopus melanogenys melanogenys* (2978); *Thamnodynastes pallidus* (2171); *Erythrolamprus cobella* (2979); *Erythrolamprus reginae semilineatus* (2980); *Lygophis lineatus* (2981); *Bothrops atrox* (1434).

