Morphological characterization and taxonomic key of tadpoles (Amphibia: Anura) from the northern region of the Atlantic Forest

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Abstract: Although anuran tadpoles are widely distributed and abundant in tropical aquatic habitats, there is a lack of taxonomic keys for the Atlantic Forest. Herein, we developed a dichotomous key for identifying the tadpoles for all species with known larval phase and already recorded in the Atlantic Forest north of the São Francisco River. We analyzed discrete characteristics of 1,042 tadpoles encompassing 63 species of 28 genera from 32 localities. The user-friendly key includes illustration and pictures, and it is a significant step towards improving our knowledge of tadpoles of the Atlantic Forest.

Keywords: larval phase; anuran amphibians; Neotropical region.

Caracterização morfológica e chave taxonômica de girinos (Amphibia: Anura) da região norte da Mata Atlântica

Resumo: Embora os girinos de anuros sejam amplamente distribuídos e abundantes em habitats aquáticos tropicais, não há chaves taxonômicas suficientes para as espécies da Mata Atlântica. Aqui, desenvolvemos uma chave dicotômica para identificar os girinos de todas as espécies com fase larval conhecida e já registradas nesse bioma, ao norte do rio São Francisco. Nós analisamos características discretas de 1,042 girinos pertencentes a 63 espécies (28 gêneros) de 32 localidades. Esta chave de identificação inclui ilustrações e imagens, sendo um passo significativo para um melhor conhecimento dos girinos da Mata Atlântica.

Palavras-chave: fase larval; anfíbios anuros; Região Neotropical.
Introduction

The majority of the more than 7,000 currently known species of anurans (AmphibiaWeb 2020, Frost 2020) have a larval phase (Altig & McDiarmid 1999). Tadpoles occur in a great variety of aquatic habitats, including ponds, streams, phytotelmata, and shallow films of water in splash zones of rivers and waterfalls (Altig & McDiarmid 1999). Tadpoles experience a variety of selective pressures in aquatic habitats and thus exhibit extensive ecological and morpho-functional variation (Duellman & Trueb 1994, Altig & McDiarmid 1999, Rolents et al. 2011, Sherratt et al. 2017, 2018).

Although the number of studies on Neotropical tadpoles is growing, there are still several knowledge gaps regarding their natural history, habitat use, microhabitat occupation, feeding behavior and ecology (Provete et al. 2012, Rossa-Feres et al. 2015). Brazil harbors the richest amphibian fauna worldwide (AmphibiaWeb 2020), yet tadpoles have been described for only about 60% of its species (Provete et al. 2012). Furthermore, this number is underestimated because many new species have been described without the larval phase being reported (Rossa-Feres et al. 2015). This gap in tadpole descriptions is further compounded by the few identification keys available for Neotropical tadpoles (e.g., Lips & Savage 1996, Rossa-Feres & Nomura 2006, Schulze et al. 2015), which are restricted to specific regions. For the Atlantic Forest, home to a remarkable diversity of anurans (more than 625 species) with high endemism (78%) (Rossa-Feres et al. 2017), identification keys are only available for the Southern and Southeastern regions (Rossa-Feres & Nomura 2006, Machado & Maltchik 2007, Pimenta et al. 2014, Fatorelli et al. 2017, Pezzuti et al. 2019). The limited number of taxonomic keys hampers the correct identification of anuran larvae, thus hindering studies on ecology, systematics and conservation (Altig & McDiarmid 1999, Andrade et al. 2007).

The Atlantic Forest north of the São Francisco River is also known as the Pernambuco biogeographical sub-region (Ribeiro et al. 2009). This sub-region is characterized by dense ombrophilous vegetation, most of it replaced by monocultures and pastures (Assis 2000, Studer et al. 2015), resulting in a vastly fragmented landscape with most fragments smaller than 50 ha and the largest less than 10,000 ha (Ribeiro et al. 2009). Together, these fragments cover about 379,818 ha of the Brazilian states of Alagoas, Pernambuco, Paraíba and Rio Grande do Norte (Ribeiro et al. 2009).

Nonetheless, 77 anuran species (12% of the known richness of the Atlantic Forest) of 34 genera and 15 families (Aromobatidae, Bufonidae, Centrolenidae, Ceratophryidae, Craugastoridae, Eleutherodactylidae, Hemiophryidae, Hylidae, Hylodidae, Leptodactylidae, Microhylidae, Odontophrynidae, Phyllomedusidae, Pipidae, and Ranidae) occur in this biogeographical region and its transitional areas (for species list and reference see Supplementary Material 1). Seven of these species are endangered (Allobates olfersioide, Adelophryne baturitensis, Chiasmocleis alagoana, Crossodactylus dantai, Hylomantis granulosa, Phyllodytes gyniastes, and Physalaemus caele), while 14 species are endemic (ICMBio 2018, Vilela et al. 2018, IUCN 2020).

Herein, we provide a user-friendly dichotomous key for anuran larvae of 63 out of 77 anuran species occurring in the Atlantic Forest north of the São Francisco River, and a morphological characterization for 28 genera and 15 species groups in those genera with great morphological diversity.

Material and Methods

We analyzed 1,042 tadpoles collected from 32 localities (Figure 1) and encompassing 63 species from 28 genera occurring in the northern region of the Atlantic Forest (north of the São Francisco River). Species of three genera occurring in the region, Pristimantis Jiménez-de-la-Espada, 1870 (Craugastoridae), Adelophryne Hoogmoed & Lescure, 1984 (Eleutherodactylidae) and Gastrotheca Fitzinger, 1843 (Hemiphractidae), were not included because they exhibit direct development (i.e., they do not go through a larval phase; Hedges et al. 2008, Duellman & Trueb 2015). Moreover, tadpoles of Vitreorana baliomma Pontes, Caramaschi & Pombal, 2014 (Centrolenidae), Ceratophrys joazeirensis Mercadal de Barrio, 1986 (Ceratophryidae), Crossodactylus dantai Carcerelli & Caramaschi, 1993 (Hylodidae), Leptodactylus ochraceus Lutz, 1930 (Leptodactylidae), and those of the hylids Boana exastis (Caramaschi & Rodrigues, 2003), Olyoloyng muriicrensis Cruz, Nunes & Lima, 2011, S. cretatus Nunes & Pombal, 2011 and Sphaenorhynchus cammaeus Roberto, Araujo-Vieira, Carvalho-e-Silva & Ávila, 2017 were not included because their tadpoles have not been described.

All examined specimens are housed in the following herpetological collections: Coleção de Anfíbios do Museu de História Natural da Universidade Federal da Bahia (UFBA), Coleção de Anfíbios da Universidade Estadual Paulista, São José do Rio Preto (DZSJRP), Coleção Herpetológica do Museu de História Natural da Universidade Federal de Alagoas (MUFAL), Coleção Herpetológica do Museu de Zoológica da Universidade Estadual de Santa Cruz (MZUESC), Coleção Herpetológica do Museu de Zoológica da Universidade Estadual de Feira de Santana (MZFS), Coleção Herpetológica da Universidade Federal do Paraíba (CHUFFP), Coleção Herpetológica da Universidade Federal de Pernambuco (CHUFFP), and Laboratório de Herpetologia da Universidade Federal de Campina Grande (LUHFECG). Specimens were identified up to species level based on one of the following methods: (i) DNA barcoding approach (fragment of mitochondrial 16S rRNA gene), (ii) observation of metamorphosed specimens in captivity, (iii) developing from eggs obtained from identified mating pairs, (iv) larvae from the same lot used in the original description of the species, or (v) direct comparison with the original description. Species nomenclature followed Frost (2020).

Because morphological features vary along tadpole’s ontogenetic development (Altig & McDiarmid 1999, Grosjean 2005, Lauffer et al. 2013), we evaluated 21 morphological characteristics in tadpoles at development stages 30–40 (Gosner 1960), and 51–58 (Niewkoop & Faber 1956) for Pipa larvae. Nevertheless, if these stages were not available, adjacent younger and older tadpoles were examined. Morphological characterization and terminology followed Altig & McDiarmid (1999): body shape in dorsal and lateral views; snout shape in dorsal and lateral views; eye position, nostrils aperture configuration; distance of nostrils from the tip of the snout and eyes; presence and position of the oral disc, distribution of marginal papillae; labial tooth row formula (LTRF); spiracle number and position; vent tube position; dorsal fin origin; dorsal and ventral fins height and contour; relative length of tail; tail tip shape; and presence of flagellum (only for those who have it). All observations were made using a Coleman® NSZ 405 stereomicroscope.

To define body morphogeometric states to standardize nomenclature, at least three taxonomically unrelated species were used. The body
contour around those corresponding shapes was blended for a better view of shape variations in one same state seeking to eliminate the effect of rotation and scaling. The resulting shapes are shown in Figure 2.

The identification key was elaborated in a taxonomically inclusive way, with terminals at family, genus, species group (following the most current phylogenetic proposals, see below) and species. Exception to two pairs of species: *Phyllodytes brevirostris* Peixoto & Cruz, 1988 and *P. edelmoi* Peixoto, Caramaschi & Freire, 2003; and the pairs *Physalaemus albifrons* (Spix, 1824) and *P. cuvieri* Fitzinger, 1826, which were reciprocally grouped together in the same terminal because no morphological variations that diagnosed these tadpoles were identified. Characters grouping monophyletic taxa were preferred over those grouping ecomorphotypes. People with different degrees of knowledge about tadpole morphology tested the key.

The characterization of genera and species groups followed the following sequence: (i) list of the species that occur in the region and the locality from where the described tadpoles were obtained, (ii) list of the examined specimens, with the following data: acronym and catalog number in scientific collections, number of individuals analyzed, range of developmental stages, and locality from where the tadpoles were

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**Figure 1.** Map of the study area, northern portion of the Atlantic Forest located north of the São Francisco River. Black circles correspond to the locations from which the analyzed tadpoles came from. Inset map: South America.
obtained, (iii) morphological characterization of specimens examined, (iv) notes: comparison with tadpoles described from other localities, if morphological differences were detected.

Results

1. Morphological characterization

Family Aromobatidae

Allobates Zimmermann & Zimmermann, 1988

Species occurring in the region. Allobates olfersioides (Lutz, 1925) (Figure 3A): Verdade & Rodrigues (2007), municipality of Rio de Janeiro, state of Rio de Janeiro, Brazil.

Specimens examined. Allobates olfersioides: MUFAL 11083, 13953 (n = 9, stages 28–32), municipality of Maceió; MUFAL 12465 (n = 11, stages 30–36), municipality of Teotônio Vilela; both from the state of Alagoas, Brazil.

Characteristics: Body ovoid in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils reniform, closer to eyes than to tip of snout. Eyes dorsal. Oral disc anteroventral, emarginate laterally. Marginal papillae arranged lateroventrally, with a wide dorsal gap. LTRF 2(2)/3. Upper jaw sheath with medial re-entrance. Spiracle sinistral. Vent tube medial. Dorsal fin originating at tail-body junction, dorsal and ventral fins parallel to longitudinal axis of tail. Tail length about 70% of total length, tail tip acute.

Notes: The tadpoles of A. olfersioides described by Verdade & Rodrigues (2007) from Tijuca, state of Rio de Janeiro, Brazil, differ from those studied here by having the LTRF 2(1)/3, nostrils circular and dorsal fin originating on the body.

Family Bufonidae

Frostius Cannatella, 1986

Species occurring in the region. Frostius pernambucensis (Bokermann, 1962) (Figure 3B): Cruz & Peixoto (1982), municipality of Recife, state of Pernambuco, Brazil.

Specimens examined. Frostius pernambucensis: MUFAL 14572 (n = 5, stages 41–42), municipality of Murici, state of Alagoas, Brazil.

Characteristics: Body ovoid in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils reniform, closer to eyes than to tip of snout. Eyes dorsal. Oral disc ventral. Marginal papillae absent. LTRF 1/1 arranged on a thick dermal fold. Spiracle sinistral. Vent tube medial. Dorsal fin originating at tail-body junction, dorsal fin slightly arched and ventral fin parallel to longitudinal axis of tail. Tail length about 70% of total length, tail tip acute.

Rhinella Fitzinger, 1826

Species occurring in the region. Rhinella crucifer (Wied-Neuwied, 1821) (Figure 3C): Ruas et al. (2012), municipality of Igrapiúna, Alagoas, Brazil.
state of Bahia, Brazil. *Rhinella granulosa* (Spix, 1824) (Figure 3D): Lynch (2006), Colombia; Mercês et al. (2009), municipality of Feira de Santana, state of Bahia, Brazil. *Rhinella hoogmoedi* Caramaschi & Pombal, 2006 (Figure 3E): Mercês et al. (2009), municipality of Igrapiúna, state of Bahia, Brazil. *Rhinella jimí* (Stevaux, 2002) (Figure 3F): Mercês et al. (2009), municipality of Feira de Santana, state of Bahia, Brazil; Tolledo & Toledo (2010), archipelago of Fernando de Noronha, state of Pernambuco, Brazil.

Specimens examined. *Rhinella crucifer*: MUFAL 15450 (n = 10, stages 35–37), municipality of Quebrangulo, state of Alagoas, Brazil. *Rhinella granulosa*: MUFAL 13877 (n = 7, stages 33–34), municipality of Arapiraca; MUFAL 13882, 13887 (n = 10, stages 38–40), municipality of Batalha; both from the state of Alagoas, Brazil. *Rhinella hoogmoedi*: MUFAL 12502 (n = 15, stages 30–37), municipality of Murici, state of Alagoas, Brazil. *Rhinella jimí*: MUFAL 13883 (n = 11, stages 30–37), municipality of Arapiraca; MUFAL 13890 (n = 5, stage 30), municipality of Jaramataia; MUFAL 13897 (n = 11, stages 37–40), municipality of Traipú; all from the state of Alagoas, Brazil; CHUFPB 28091 (n = 20, stages 30–40), municipality of Areia, state of Paraíba, Brazil.

Characteristics: Body ovoid or elliptical in dorsal view, globular-depressed in lateral view. Snout oval or rounded in dorsal view, oval in lateral view. Nostrils reniform, closer to eyes than to tip of snout. Eyes dorsal. Oral disc ventral, emarginate laterally. Marginal papillae arranged laterally, with a wide dorsal gap and a wide ventromedial gap. LTRF 2(2)/3. Spiracle sinistral. Vent tube medial. Dorsal fin originating at tail-body junction, dorsal fin and ventral fin arched. Tail length approximately 60% of total length, tail tip rounded.

**Family Hylidae**

*Aplastodiscus* Lutz, 1950

Species occurring in the region. *Aplastodiscus sibilatus* (Cruz, Pimenta & Silvano, 2003) (Figure 3G): Mercês & Juncá (2010), municipality of Santa Terezinha, state of Bahia, Brazil.

Specimens examined. *Aplastodiscus sibilatus*: MUFAL 10847 (n = 9, stages 30–40), municipality of Murici, state of Alagoas, Brazil.

Characteristics: Body elliptical in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils elliptical, closer to eyes than to tip of snout. Eyes dorsal. Oral disc ventral, with two emarginations on posterior margin. Marginal papillae arranged lateroventrally, with a short dorsal gap. LTRF 3(1,3)/5(1). Spiracle sinistral. Vent tube dextral. Dorsal fin originating at tail, dorsal and ventral fins parallel to longitudinal axis of tail. Tail length about 70% of total length, tail tip acute.

*Boana* Gray, 1825

Species occurring in the region. *Boana albopunctata* species group (Faivovich et al. 2005) – *Boana raniceps* (Cope, 1862) (Figure 3H): Kolene et al. (2008), Argentina; Schulze et al. (2015), Bolivia. *Boana faber* species group (Faivovich et al. 2005) – *Boana albomarginata* (Spix, 1824) (Figure 4A): Peixoto & Cruz (1983), municipalities of

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Figure 3. Lateral, dorsal and ventral views (scale = 3mm) and oral disc (scale = 1mm) of tadpoles occurring in the north of the Atlantic Forest.
Rio de Janeiro (Grumari’s administrative region) and Itaguai; both from the state of Rio de Janeiro, Brazil, and municipality of Recife, state of Pernambuco, Brazil. Boana crepitans (Wied-Neuwied, 1824) (Figure 4B): Kenny (1968), Trinidad; Lynch (2006), Colombia; Casal & Juncá (2008), municipality of Feira de Santana, state of Bahia, Brazil. Boana faber (Wied-Neuwied, 1821) (Figure 4C): Cej (1980) and Kolenc et al. (2008), Argentina. Boana pulchella species group (Faivovich et al. 2005) – Boana freicanecae (Carnaual & Peixoto, 2004) (Figure 4D): Carnaval & Peixoto (2004), municipality of Jaqueira, state of Pernambuco, Brazil. Boana punctata species group (Faivovich et al. 2005) – Boana atlantica (Caramaschi & Velosa, 1996) (Figure 4E): Nascimento et al. (2009), municipality of Maceió, state of Alagoas, Brazil. Boana semilineata species group (Faivovich et al. 2005) – Boana semilineata (Spix, 1824) (Figure 4F): Bokermann (1963), municipality of Piassaguera, state of São Paulo, Brazil.

Specimens examined. Boana albomarginata: MUFAL 10146 (n = 15, stages 30–34), municipality of Maceió, state of Alagoas; CHUFPB 27211 (n = 2, stage 37), municipality of Macaíba, state of Rio Grande do Norte, Brazil. Boana atlantica: MUFAL 4755 (n = 6, stages 30–40), municipality of Maceió, state of Alagoas, Brazil. Boana crepitans: MUFAL 15452 (n = 5, stages 27–29), municipality of Quebrangulo, state of Alagoas, Brazil. Boana faber: MUFAL 15453 (n = 10, stage 26), municipality of Porto Seguro, state of Bahia, Brazil; this locality is from south of the São Francisco River, but it was considered here because although there are records of this species for the northern Atlantic Forest (Almeida et al. 2016), there are no tadpole specimens. Boana freicanecae: MUFAL 10779 (n = 7, stages 30–34), municipality of Murici, state of Alagoas, Brazil. Boana raniceps: MUFAL 12497 (n = 9, stages 36–39), municipality of Barra de Santo Antônio, state of Alagoas, Brazil; CHUFPB 28471–72 (n = 4, stages 26–31), municipality of João Pessoa, state of Paraíba, Brazil; CHUFPB 28221 (n = 2, stages 31–34), municipality of Macaíba, state of Rio Grande do Norte, Brazil. Boana semilineata: MUFAL 9711 (n = 10, stages 30–32), municipality of Maceió, state of Alagoas, Brazil; CHUFPE-A 1130 (n = 1, stages 38), municipality of Vicência, state of Pernambuco, Brazil.

Characteristics: Boana albopunctata species group – Body ovoid in dorsal view, globular-depressed in lateral view. Snout oval in dorsal view, acuminate in lateral view. Nostrils reniform, equally distant from eyes and tip of snout. Eyes dorsal. Oral disc ventral, with two emarginations on posterior margin. Marginal papillae arranged lateroventrally, with a wide dorsal gap. LTRF 2(1,2)/3(1). Spiracle sinistral. Vent tube dextral. Dorsal fin originating at tail-body junction, dorsal fin arched, ventral fin parallel to longitudinal axis of tail. Tail length approximately 60% of total length, tail tip acute.

Boana faber species group – Body ovoid in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils reniform, equally distant from eyes and tip of snout. Eyes dorsal. Oral disc anteroventral, with two emarginations on posterior margin. Marginal papillae arranged lateroventrally, with a short dorsal gap. LTRF 2(1)/3(1). Spiracle sinistral. Vent tube dextral.

Figure 4. Lateral, dorsal and ventral views (scale = 3mm) and oral disc (scale = 1mm) of tadpoles occurring in the north of the Atlantic Forest.
Dorsal fin originating at tail-body junction, dorsal and ventral fins parallel to longitudinal axis of tail. Tail length approximately 60% of total length, tail tip acute.

**Boana pulchella** species group – Body elliptical in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils reniform, equally distant from eyes and tip of snout. Eyes dorsal. Oral disc ventral, two emarginations on posterior margin. Marginal papillae arranged lateroventrally, with a wide dorsal gap. LTRF 2(1,2)/4(1). Spiracle sinistral. Vent tube dextral. Dorsal fin originating at tail-body junction. Dorsal and ventral fins parallel to longitudinal axis of tail. Tail length approximately 60% of total length, tail tip acute.

**Boana punctata** species group – Body elliptical in dorsal view, globular-depressed in lateral view. Snout rounded in dorsal view, oval in lateral view. Nostrils reniform, equally distant from eyes and tip of snout. Eyes dorsal. Oral disc anteroventral, two emarginations on posterior margin. Marginal papillae arranged lateroventrally, with a wide dorsal gap. LTRF 2(1,2)/4(1). Spiracle sinistral. Vent tube dextral. Dorsal fin originating at tail-body junction, dorsal and ventral fins parallel to longitudinal axis of tail. Tail length approximately 60% of total length, tail tip acute.

**Boana semilineata** species group – Body oval in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils reniform, equally distant from eyes and tip of snout. Eyes dorsal. Oral disc anteroventral, two emarginations on posterior margin. Marginal papillae arranged lateroventrally, with a wide dorsal gap. LTRF 2(1,2)/4(1). Spiracle sinistral. Vent tube dextral. Dorsal fin originating at tail-body junction, dorsal and ventral fins arched. Tail length approximately 60% of total length, tail tip acute.

**Corythomantis** Boulenger, 1896

 Species occurring in the region. **Corythomantis greeningi** Boulenger, 1896 (Figure 4G): Juncã et al. (2008), municipalities of Feira de Santana and Morro do Chapéu; both from the state of Bahia, Brazil.

 Specimens examined. **Corythomantis greeningi**: MUFAL 13688 (n = 11, stages 30–40), municipality of Murici, state of Alagoas, Brazil; CHUFPB 28023 (n = 20, stages 36–38), municipality of Macaíba, state of Rio Grande do Norte, Brazil.

 Characteristics: Body elliptical-elongated in dorsal view, globular-depressed in lateral view. Snout rounded in dorsal view, sloped in lateral view. Nostrils rounded, closer to eyes than to tip of snout. Eyes dorsal. Oral disc ventral, two emarginations on posterior margin. Marginal papillae without gaps. LTRF 6(6)/7(8)/1(1). Spiracle sinistral. Vent tube dextral. Dorsal fin originating at tail-body junction, dorsal and ventral fins parallel to longitudinal axis of tail. Tail length about 70% of total length, tail tip acute.

**Dendropsophus** Fitzinger, 1843

 Species occurring in the region. **Dendropsophus decipiens** species group (Faivovich et al. 2005) – **Dendropsophus haddadi** (Bastos & Pombal, 1996) (Figure 4H): Abreu et al. (2013), municipality of Mata de São João, state of Bahia, Brazil. **Dendropsophus oliveirai** (Bokermann, 1963) (Figure 5A): Pugliese et al. (2000), municipality of Quebranguito, state of Alagoas, Brazil. **Dendropsophus leucophyllatus** species group (Faivovich et al. 2005) – **Dendropsophus soarezi** (Caramaschi & Jim, 1983) (Figure 5C), Gomes & Peixoto (1991b), municipality of Magé, state of Rio de Janeiro and municipality of Linhares, state of Espírito Santo, Brazil. **Dendropsophus microcephalus** species group (Faivovich et al. 2005) – **Dendropsophus branneri** (Cochran, 1948) (Figure 5D): Abreu et al. (2015a), municipality of Igarassu, state of Pernambuco, Brazil. **Dendropsophus nanus** (Boulenger, 1889) (Figure 5E): Lavilla (1990), Argentina; Hero (1990), municipality of Manaus, state of Amazonas, Brazil; Schulze et al. (2015), Bolivia. **Dendropsophus studerai** (Carvalho-e-Silva et al. 2003) (Figure 5F): Carvalho-e-Silva et al. (2003), municipality of Quebrangulo, state of Alagoas, Brazil. **Dendropsophus minutus** species group (Faivovich et al. 2005) – **Dendropsophus minutus** (Peters, 1872) (Figure 5G): Bokermann (1963), municipality of Campo Grande, state of São Paulo, Brazil; Vizzotto (1967), state of São Paulo, Brazil; Kenny (1968), Trinidad; Duellman (1978), Ecuador; Hero (1990), municipality of Manaus, state of Amazonas, Brazil; Heyer et al. (1990), municipality of Salesópolis, state of São Paulo, Brazil.

 Specimens examined. **Dendropsophus branneri**: MUFAL 13943 (n = 15, stages 28–31), municipality of Maceió, state of Alagoas, Brazil; CHUFPB 28052 (n = 15, stages 38), municipality of Macaíba, state of Rio Grande do Norte, Brazil; CHUFPB 28513–14, 28513, 28575 (n = 6, stages 30–36), municipality of João Pessoa, state of Paraíba, Brazil. **Dendropsophus elegans**: MUFAL 10131, 11260 (n = 10, stages 32–37), municipality of Itabangu, state of Alagoas, Brazil. **Dendropsophus haddadi**: MUFAL 10167 (n = 8, stages 30–37), municipality of Maceió, state of Alagoas, Brazil. **Dendropsophus minutus**: MUFAL 12479 (n = 15, stages 30–34), municipality of Limeiro de Anadja, state of Alagoas, Brazil; CHUFPB 28006–8 (n = 20, stages 35–39), municipality of Macaíba, state of Rio Grande do Norte, Brazil. **Dendropsophus nanus**: MUFAL 12470 (n = 1, stage 40), municipality of Coruripe, state of Alagoas, Brazil; CHUFPB 28452 (n = 4, stages 36–39), municipality of Macaíba, state of Rio Grande do Norte, Brazil. **Dendropsophus oliveirai**: MUFAL 11259 (n = 4, stages 35–39), municipality of São José da Tapera, state of Alagoas, Brazil; CHUFPB 28055 (n = 12, stages 31–40), municipality of Macaíba, state of Rio Grande do Norte, Brazil. **Dendropsophus soarezi**: MUFAL 10206 (n = 9, stages 37–40), municipality of Coruripe, state of Alagoas, Brazil; CHUFPB 28056–59 (n = 20, stages 30–38), municipality of Macaíba, state of Rio Grande do Norte, Brazil. **Dendropsophus studerai**: MUFAL 15459–60 (n = 4, stages 37–38), municipality of Quebrangulo, state of Alagoas, Brazil.

 Characteristics: **Dendropsophus decipiens** species group – Body ovoid, elongated in dorsal view, triangular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils circular, anteriorly positioned. Oral disc anterior, not emarginate. Marginal papillae arranged ventrolaterally, with a wide dorsal gap. LTRF 0/0. Spiracle sinistral. Vent tube dextral. Dorsal fin originating at tail-body junction, dorsal and ventral fins slightly arched. Tail length about 60% of total length, tail tip acute.
junction, dorsal and ventral fins slightly arched. Tail length about 60% of total length, tail tip acute.

**Dendropsophus marmoratus** species group – Body elliptical-elongated in dorsal view, triangular-depressed in lateral view. Snout rounded in dorsal view, oval in lateral view. Nostrils circular, anteriorly positioned, much closer to tip of snout than to eyes. Eyes laterally positioned. Oral disc anterior, not emarginate. Marginal papillae arranged ventrolaterally, with one dorsal gap and one pair of narrow ventrolateral gaps. LTRF 0/1. Spiracle sinistral. Vent tube dextral. Dorsal fin originating at body, dorsal and ventral fins slightly arched. Tail length about 60% of total length, tail tip acute.

**Dendropsophus microcephalus** species group – Body ovoid, elongated in dorsal view, triangular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils circular, anteriorly positioned, much closer to tip of snout than to eyes. Eyes laterally positioned. Oral disc anterior, not emarginate, modified in a protractile and conic-shaped tube. Marginal papillae absent. LTRF 0/0. Spiracle sinistral. Vent tube dextral. Dorsal fin originating at body or tail-body junction, dorsal fin slightly arched, ventral fin parallel to longitudinal axis of tail. Tail length about 60–70% of total length, tail tip acute, with flagellum.

**Dendropsophus minutus** species group – Body elliptical-elongated in dorsal view, triangular in lateral view. Snout rounded in dorsal view and truncate in lateral view. Nostrils circular, anteriorly positioned, much closer to tip of snout than to eyes. Eyes laterally positioned. Oral disc anterior, not emarginate. Marginal papillae arranged ventrolaterally, with a wide dorsal gap. LTRF 1/2. Spiracle sinistral. Vent tube dextral. Dorsal fin originating at body, dorsal and ventral fins arched. Tail length about 60% of total length, tail tip acute, with flagellum.

Notes: Tadpoles of *D. minutus* vary in LTRF, with the specimens analyzed here having 1/2, while the specimens analyzed by Rossa-Feres & Nomura (2006) exhibiting 0/0, 0/1 and 1/2.

**Oloolygon** Fitzinger, 1843

Species occurring in the region. *Oloolygon melanodactyla* (Lourenço et al. 2014) (Figure 5H): Abreu et al. (2015b), municipality of Mata de São João, state of Bahia, Brazil. *Oloolygon skuki* (Lima, Cruz, & Azevedo, 2011) (Figure 6A): Rodrigues et al. (2017), municipality of Maceió, state of Alagoas, Brazil.

Specimens examined. *Oloolygon skuki*: MUFAL 10200, 10161, 11041, 11052, 11062, 11085 (n = 17, stages 31–40), municipality of Maceió, state of Alagoas, Brazil. *Oloolygon melanodactyla*: UFBA 11878 (n = 1, stage 31), municipality of Mata de São João, state of Bahia, located south of the São Francisco River. This locality was considered because although there are records for this species for the northern Atlantic Forest (Almeida et al. 2016), there are no tadpole specimens.

Characteristics: Body elliptical in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils circular, closer to eyes than to tip of snout or equally distant. Eyes dorsal. Oral disc ventral, not emarginated. Marginal papillae arranged...
ventrolaterally, with a wide dorsal gap. LTRF 2/3 or 2(2)/3. Spiracle sinistral. Vent tube dextral. Dorsal fin originating at the end of body, dorsal and ventral fins parallel to longitudinal axis of tail. Tail length about 60% of total length, tail tip acute.

**Phyllodytes** Wagler, 1830

Species occurring in the region. *Phyllodytes acuminatus* Bokermann, 1966 (Figure 6B): Campos et al. (2014), municipality of Buíque, state of Pernambuco, Brazil. *Phyllodytes brevirostris* Peixoto and Cruz, 1988: Vieira et al. (2009), municipality of Cruz do Espírito Santo, state of Paraíba, Brazil. *Phyllodytes edelmoi* Peixoto et al. 2003 (Figure 6C): Peixoto et al. (2003), municipality of Maceió, state of Alagoas, Brazil. *Phyllodytes gyrinaethes* Peixoto et al. 2003 (Figure 6D): Peixoto et al. (2003), municipality of Murici, state of Alagoas, Brazil.

**Scinax** Wagler, 1830

Species occurring in the region. *Scinax rostratus* species group (Faivovich et al. 2005) – *Scinax auratus* (Wied-Neuwied, 1821). Although this species was included in the *Scinax ruber* clade, it was not currently associated with any species group by Faivovich et al. (2005). Here this species was treated as related to *S. rostratus* group by overall morphological resemblance of their tadpoles, and for sharing some diagnostic larval characteristics with this group.
(Faivovich 2002), see characteristics; Figure 6E): Alves et al. (2004), municipality of Quebrangulo, state of Alagoas, Brazil. *Scinax nebulosus* (Spix, 1824) (Figure 6F): Gomes et al. (2014), municipality of Cabo de Santo Agostinho, state of Pernambuco, Brazil. Species of the *Scinax* unassigned to a species group (previously in the “*Scinax ruber* clade”, Faivovich et al. 2005) – *Scinax eurydice* (Bokermann, 1968) (Figure 6G); Wogel et al. (2000), municipality of Saquarema, state of Rio de Janeiro, Brazil. *Scinax fuscovarius* (Lutz, 1925) (Figure 6H): Vizotto (1967), state of São Paulo, Brazil; Fabrezi & Vera (1997), Argentina; Schulze et al. (2015), Bolivia. *Scinax fuscomarginatus* (Lutz, 1925) (Figure 6G): Wogel et al. (2000), municipality of Saquarema, state of Rio de Janeiro, Brazil. *Scinax fuscovarius* (Miranda-Ribeiro, 1937) (Figure 7B): Carneiro et al. (2004), municipality of Santa Terezinha, state of Bahia, Brazil. *Scinax x-signatus* (Spix, 1824) (Figure 7C): Leon (1975), Venezuela; Lynch (2006), Colombia.

Specimens examined. *Scinax auratus*: MUFAL 15461 (n = 10, stages 35–37), municipality of Quebrangulo, state of Alagoas, Brazil. *Scinax eurydice*: MUFAL 13497 (n = 3, stages 36–37), municipality of Maceió, state of Alagoas, Brazil. *Scinax fuscomarginatus*: MUFAL 13936 (n = 15, stages 30–32), municipality of Satuba, state of Alagoas, Brazil. *Scinax fuscomarginatus*: CHUFPB 28033 (n = 15, stages 32–37), municipality of Macaíba, state of Rio Grande do Norte, Brazil. *Scinax flavovittatus*: MUFAL 3785 (n = 2, stages 30–40), municipality of Limoeiro de Anadia; both from the state of Alagoas, Brazil. *Scinax pachycrus*: MUFAL 15449 (n = 6, stages 35–36), municipality of Água Branca, state of Alagoas, Brazil; CHUFPB 28034–35 (n = 11, stages 30–32), municipality of Macaíba, state of Rio Grande do Norte, Brazil. *Scinax x-signatus*: MUFAL 11023 (n = 2, stage 30), municipality of Maceió, state of Alagoas, Brazil; CHUFPB 28497 (n = 1, stage 25), municipality of João Pessoa, state of Paraíba, Brazil; CHUFPB 28037 (n = 10, stages 35–40), municipality of Macaíba, state of Rio Grande do Norte, Brazil.

Characteristics: *Scinax rostratus* species group – Body elliptical in dorsal view, triangular-depressed in lateral view. Snout rounded in dorsal view, oval in lateral view. Nostrils circular, slightly closer to eyes than to tip of snout. Eyes lateral. Oral disc anteroventral, two emarginations on lower margin, labial arm present. Marginal papillae arranged ventrolaterally, with a wide dorsal gap, absent at the labial arm. LTRF 2(2)/3(1), with the P3 located at end of labial arm. Spiracle sinistral. Vent tube dextral. Dorsal fin originating at posterior third of body, dorsal fin and ventral fins slightly arched. Tail length about 65% of total length, tail tip acute.

*Scinax ruber* clade – Body elliptical in dorsal view, triangular or triangular-depressed in lateral view. Snout rounded in dorsal view, oval or truncate in lateral view. Nostrils oval, closer to tip of snout than to eyes. Eyes lateral. Oral disc anteroventral, two emarginations on lower margin. Marginal papillae arranged ventrolaterally, with a wide dorsal gap. LTRF 2(2)/3 [exception in *S. pachycrus*: 2(2)/3(1)]. Spiracle

Figure 10. Lateral, dorsal and ventral views (scale = 3mm) and oral disc (scale = 1mm) of tadpoles occurring in the north of the Atlantic Forest.

http://www.scielo.br/bn

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Identification key of Atlantic Forest’s tadpoles

60% of total length, tail tip acute.

*Sphaenorhynchus* Tschudi, 1838
Species occurring in the region. *Sphaenorhynchus prasinus* Bokermann 1973 (Figure 7D); Bokermann (1973), municipality of Ilhêus, state of Bahia, Brazil.

Specimens examined. *Sphaenorhynchus prasinus*: MZUESC (these tadpoles were obtained in a recent sampling, right on with the closing of Universities during COVID-19 pandemic, preventing us from getting voucher numbers for these specimens, n = 10, stages 33–38), municipality of Ilhêus, state of Bahia, Brazil, located at south of the São Francisco River. They were included because although there are records of this species for the northern Atlantic Forest (Almeida et al. 2016), there are no tadpole specimens.

Characteristics: Body ovoid in dorsal view, triangular-depressed in lateral view. Snout rounded in dorsal view, sloped in lateral view. Nostrils reniform, closer to tip of snout than to eyes. Eyes lateral. Oral disc anteroventral, not emarginate. Marginal papillae arranged ventrolaterally, with a wide dorsal gap, few large marginal papillae (highlighted papillae) on the anterolateral and posterolateral margins (large papillae about twice the size of the small papillae and alternating among them). LTRF 2(2)/3(1). Spiracle sinistral. Vent tube medial. Dorsal fin originating at tail-body junction, dorsal fin parallel to longitudinal axis of tail. Tail length approximately 65% of total length, tail tip acute.

*Trachycephalus* Tschudi, 1838
Species occurring in the region. *Trachycephalus mesophaeus* (Hensel, 1867) (Figure 7E): Lutz (1973), municipality of Saquarema, state of Rio de Janeiro, Brazil; Carvalho-e-Silva et al. (2002), municipality of Rio de Janeiro, state of Rio de Janeiro, and municipality of Ubatuba, state of São Paulo, Brazil; Prado et al. (2003), municipality of Ubatuba, state of São Paulo, and municipality of Cariacica, state of Espírito Santo, Brazil.

Specimens examined. *Trachycephalus mesophaeus*: MUFAL 15457 (n = 6, 31–34), municipality of Porto Seguro, state of Bahia, Brazil, located at south of the São Francisco River. They were included because although there are records of this species for the northern Atlantic Forest (Almeida et al. 2016), there are no tadpole specimens.

Characteristics: Body elliptical in dorsal view, triangular-depressed in lateral view. Snout rounded in dorsal view, sloped in lateral view. Nostrils circular, closer to eyes than to tip of snout. Eyes lateral. Oral disc anteroventral, not emarginate. Marginal papillae arranged ventrolaterally, with a wide dorsal gap. LTRF 4(1,2,4)/6(1). Spiracle sinistral. Vent tube medial. Dorsal fin originating at tail-body junction, dorsal fin parallel to longitudinal axis of tail and ventral fin slightly arched. Tail length about 70% of total length, tail tip acute.

*Leptodactylus* Fitzinger, 1826
Species occurring in the region. *Leptodactylus fuscus* species group (de Sá et al. 2014) – *Leptodactylus caatingae* (Magalhães et al. 2013a) (Figure 7G): municipality of Macaíba, state of Rio Grande do Norte, Brazil. *Leptodactylus fuscus* (Schneider, 1799) (Figure 7H): Kenny (1968), Trinidad; Lescure (1972), French Guiana; Hero (1990), municipality of Manaus, state of Amazonas, Brazil; Rada-de-Martínez (1990), Venezuela; Lynch (2006), Colombia. *Leptodactylus mystaceus* (Spix, 1824) (Figure 8A): Duellman (1978), Ecuador; Hero (1990), municipality of Manaus, state of Amazonas, Brazil; Heyer (1978), Ecuador. *Leptodactylus troglodytes* Lutz, 1926 (Figure 8B): Casco & Peixoto (1985), municipality of Cabaceiras, state of Paraíba, Brazil; Kokubum & Maciel (2009), municipality of Cocos, state of Bahia, and municipality of Buritizeiro, state of Minas Gerais, Brazil. *Leptodactylus latrans* species group (de Sá et al. 2014) – *Leptodactylus macrosternum* Miranda-Ribeiro, 1926 (Figure 8C): Dixon & Staton (1976), Venezuela. *Leptodactylus melanomos* species group (de Sá et al. 2014) – *Leptodactylus natalensis* Lutz, 1930 (Figure 8D): Oliveira & Lirio-Júnior (2000), municipality of São Cristóvão, state of Sergipe, Brazil; Dubex et al. (2020a), municipality of Teotônio Vilela, state of Alagoas, and municipality of Ribeirão, Pernambuco state, Brazil. *Leptodactylus pentadactylus* species group (de Sá et al. 2014) – *Leptodactylus vastus* Lutz, 1930 (Figure 8E): Vieira et al. (2007a), municipality of João Pessoa, state of Paraíba, Brazil; Schulze et al. (2015), Bolivia.

Specimens examined. *Leptodactylus caatingae*: CHUFPB 27232, 28001, 28217 (n = 20, stage 36), municipality of Macaíba, state of Rio Grande do Norte, Brazil. *Leptodactylus fuscus*: CHUFPB 28013 (n = 7, stages 36–40), municipality of Macaíba, state of Rio Grande do Norte, Brazil; MUFAL 13938 (n = 10, stages 35–39), municipality of Maceió, state of Alagoas, Brazil; CHUFPE-A 1129 (n = 20, stages 34–36), municipality of Recife, state of Pernambuco, Brazil. *Leptodactylus macrosternum*: MUFAL 11022 (n = 8, stage 31), municipality of Maceió, state of Alagoas, Brazil; CHUFPB 28002–5 (n = 20, stages 32–34), municipality of Macaíba, state of Rio Grande do Norte, Brazil. *Leptodactylus mystaceus*: MUFAL 13408 (n = 16, stages 34–40), municipality of Maceió, state of Alagoas, Brazil. *Leptodactylus natalensis*: MUFAL 12465 (n = 10, stages 36–37), municipality of Teotônio Vilela, state of Alagoas, Brazil. *Leptodactylus troglodytes*: CHUFPB 28071 (n = 8, stages 35–39), municipality of Macaíba, and CHUFPB 28208 (n = 3 stage 35), municipality of Nísia Floresta; both in state of Rio Grande do Norte, Brazil; MUFAL 12459 (n = 10, stages 28–31), municipality of Junqueiro, state of Alagoas, Brazil. *Leptodactylus vastus*: MUFAL 10216 (n = 9, stages 31–36), municipality of Maceió, and MUFAL 10148 (n = 2, stage 40), municipality of Satuba;
both from the state of Alagoas, Brazil; CHUFPB 28603 (n = 8, stage 29), municipality of João Pessoa, state of Paraíba, Brazil; CHUFPB 28066–69 (n = 20, stages 31–40), municipality of Macaíba, state of Rio Grande do Norte, Brazil.

Characteristics: *Leptodactylus fuscus* species group – Body elliptical or ovoid in dorsal view, globular-depressed in lateral view. Snout oval or rounded in dorsal view, oval in lateral view. Nostrils circular, generally located closer to tip of snout than to eyes. Eyes dorsal. Oral disc anteroventral, not emarginate. Marginal papillae arranged ventrolaterally, with a wide dorsal gap, anterior margin of oral disc totally fused with body wall. LTRF 2(2)/3(1). Spiracle sinistral. Vent tube medial. Dorsal fin originating at tail-body junction, dorsal and ventral fins slightly arched. Tail length approximately 60% of total length, tail tip acute.

*Leptodactylus latrans* species group – Body ovoid, elongated in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils circular, generally located closer to tip of eyes than to snout. Eyes dorsal. Oral disc anteroventral, not emarginate. Marginal papillae arranged ventrolaterally, with a wide dorsal gap, anterior margin of oral disc totally fused with body wall. LTRF 2/3. Spiracle sinistral. Vent tube medial. Dorsal fin originating at tail-body junction, dorsal and ventral fins slightly arched. Tail length approximately 60% of total length, tail tip acute.

*Leptodactylus melanopterus* species group – Body oval, elongated in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils circular, located closer to eyes than to snout. Eyes dorsal. Oral disc ventral, not emarginate, anterior margin of oral disc totally fused with body wall. Marginal papillae arranged ventrolaterally, with a wide dorsal gap. LTRF 2/3. Spiracle sinistral. Vent tube medial. Dorsal fin originating at tail-body junction, dorsal and ventral fins parallel to longitudinal axis of tail. Tail length approximately 70% of total length, tail tip acute.

*Physalaemus Fitzinger, 1826*

Species occurring in the region. *Physalaemus albifrons* (Spix, 1824) (Figure 8F): Oliveira et al. (2010), municipality of Brotas de Macaúbas, state of Bahia, Brazil. *Physalaemus caeae* Pombal & Madureira 1997: Pombal & Madureira (1997), municipality of Passo de Camaragibe, state of Alagoas, Brazil. *Physalaemus cuvieri* Fitzinger, 1826 (Figure 8G): Bokermann (1962), municipality of Diadema, state of São Paulo, Brazil; Cei (1980), Argentina; Heyer et al. (1990), municipality of Boracéia, state of São Paulo, Brazil.
Species examined. Physalaemus albifrons: CHUFPB 28453 (n = 10, stages 37–40), municipality of Macaíba, state of Rio Grande do Norte, Brazil; UFBA 10013 (n = 8, stages 33–37), municipality of Pilão Arcado, state of Bahia, Brazil. Physalaemus caete: exceptionally for Physalaemus caete Norte, Brazil; UFBA 10013 (n = 8, stages 33–37), municipality of Pilão Arcado, state of Bahia, Brazil. Physalaemus cuvieri: MUFAL 10208 (n = 11, stages 34–40), municipality of Coruripe, state of Alagoas, Brazil; CHUFPB 28025 (n = 20, stages 37–40), municipality of Macaíba, state of Rio Grande do Norte, Brazil.

Characteristics: Body ovoid in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Eyes dorsal. Nostrils circular, generally located closer to eyes than to tip of snout. Oral disc ventral, emarginate laterally, anterior margin of oral disc totally fused with body wall. Marginal papillae with wide dorsal gap and two small ventrolateral gaps (not ventromedial and ventrolateral gaps in P. caete). LTRF 2(2/3(1)[2]. Spiracle sinistral. Vent tube dextral. Dorsal fin originating at tail-body junction, dorsal fin arched and ventral fin parallel to longitudinal axis of tail. Tail length approximately 60% of total length, tail tip acute.

Notes: Pombal & Madureira (1997) described the vent tube of P. caete as medial even though their illustration shows the tube sloping towards the right side, which is characteristic of a dextral opening. The P. cuvieri tadpoles characterized by Rossa-Feres & Nomura (2006) from Nova Itapirema, state of São Paulo, Brazil, differs from those studied here by having a medial vent tube opening. Bokermann (1962) reported a LTRF 2(2/3) for P. cuvieri tadpoles from Posto Jacaré, state of Mato Grosso, Brazil.

Pleurodema Tschudi, 1838
Species occurring in the region. Pleurodema diplolister (Peters, 1870) (Figure 8H): Peixoto (1982), municipality of Mossoró, state of Rio Grande do Norte, Brazil.

Specimens examined. Pleurodema diplolister: CHUFPB 28026–27 (n = 12, stages 32–40), municipality of Macaíba, state of Rio Grande do Norte, Brazil; MZFS 326 (n = 4, stages 35–36), municipality of Feira de Santana, state of Bahia, Brazil.

Characteristics: Body oval, elongated in dorsal view, globular-depressed in lateral view. Snout oval in dorsal view, sloped in lateral view. Nostrils circular or oval, generally located at midway between the eyes and tip of snout. Eyes dorsal. Oral disc anteroventral, emarginate laterally. Marginal papillae arranged ventrolaterally, anterior margin of oral disc totally fused with body wall. Marginal papillae with wide dorsal gap. LTRF 2(2/3(1). Spiracle sinistral. Vent tube medial. Dorsal fin originating on the body and slightly arched, and ventral fin parallel to longitudinal axis of tail. Tail length approximately 65% of total length, tail tip acute.

Notes: The tadpoles of P. diplolister described by Peixoto (1982) from Mossoró, state of Rio Grande do Norte, Brazil, differ from those studied here by having a sinistral vent tube opening, although the illustration clearly shows a dextral opening.

Pseudopaludicola Miranda-Ribeiro, 1926
Species occurring in the region. Pseudopaludicola mystacalis (Cope, 1887) (Figure 9A): Schulze et al. (2015), Bolivia. Pseudopaludicola pocoto Magalhães et al. 2014 (Figure 9B): Magalhães et al. (2014), municipality of Macaíba, state of Rio Grande do Norte, Brazil.

Specimens examined. Pseudopaludicola mystacalis: CHUFPB 28030 (n = 10, stages 30–40), municipality of Arês, state of Rio Grande do Norte, Brazil; MUFAL 13956 (n = 1, stage 40), municipality of Satuba, state of Alagoas, Brazil. Pseudopaludicola pocoto: CHUFPB 28021–22 (n = 20, stages 36–40), municipality of Macaíba; CHUFPB 29209 (n = 20, stages 30–40), municipality of Nísia Floresta; both in state of Rio Grande do Norte, Brazil.

Characteristics: Body elliptical or ovoid in dorsal view, globular-depressed in lateral view. Snout rounded or oval in dorsal view, oval in lateral view. Nostrils circular, located closer to eyes than to tip of snout. Eyes dorsal. Oral disc ventral, emarginate laterally. Marginal papillae with wide dorsal gap and two small ventrolateral gaps, anterior margin of oral disc totally fused with body, LTRF 2(2)/2. Spiracle sinistral. Vent tube dextral. Dorsal fin originating at tail-body junction, dorsal fin arched and ventral fin parallel to longitudinal axis of tail. Tail length approximately 60% of total length, tail tip acute.

Family Microhylidae
Chiasmocleis Méhely, 1904
Species occurring in the region. Chiasmocleis alagoana Cruz, Caramaschi & Freire, 1999 (Figure 9C): Nascimento & Skuk (2006), municipality of Maceió, state of Alagoas, Brazil.

Specimens examined. Chiasmocleis alagoana: MUFAL 9785 (n = 4, stages 30–31), municipality of Maceió, state of Alagoas, Brazil.

Characteristics: Body rounded in dorsal view, triangular-depressed in lateral view. Snout rounded in dorsal view and truncate in lateral view. Nostrils absent in early development stages. Eyes lateral. Oral disc lacking keratinized structures, semicircular lips flaps over oral opening. Marginal papillae absent. Spiracle long, ventrally positioned, posteroventrally directed, reaching and overlapping the vent tube opening. Vent tube medial. Dorsal fin originating at posterior end of body, dorsal and ventral fins arched. Tail length approximately 60% of total length, tail tip acute with flagellum.

Dermatotus Méhely, 1904
Species occurring in the region. Dermatonotus muelleri (Boettger, 1885) (Figure 9D): Cei (1980) and Lavilla (1992), Argentina; Vizotto (1967), state of São Paulo, Brazil; Schulze et al. (2015), Bolivia.

Specimens examined. Dermatonotus muelleri: MUFAL 13687, 12472 (n = 3, stages 35–37), municipality of Coruripe, MUFAL 13874 (n = 7, stages 30–38), municipality of Arapiraca, and MUFAL 13910 (n = 15, stages 30–35), municipality of Delmiro Gouveia; all from the state of Alagoas, Brazil; CHUFPB 28083–90 (n = 20, stages 38–40), municipality of Macaíba, state of Rio Grande do Norte, Brazil.

Characteristics: Body rounded in dorsal view, triangular in lateral view. Snout rounded in dorsal view, truncate in lateral view. Nostrils absent in early development stages. Eyes lateral. Oral disc lacking keratinized structures, square lip flaps over oral opening. Marginal papillae absent. Spiracle long, tubular, ventrally positioned, extending posteroventrally reaching and overlapping vent tube. Vent tube medial. Dorsal fin originating on tail, dorsal and ventral fins arched; dorsal fin lacking pigmentation posteriorly. Tail length about 60% of total length, tail tip acute.

Elachistocleis Parker, 1927
Species occurring in the region. Elachistocleis cesarii (Miranda-Ribeiro, 1920) (Figure 9E): Magalhães et al. (2012), municipality of Macaíba, state of Rio Grande do Norte, Brazil.
Specimens examined. *Elachistocleis cesarii*: CHUFPB 28009–12 (n = 20, stage 28), municipality of Macaíba, state of Rio Grande do Norte, Brazil.

Characteristics: Body rounded in dorsal view, triangular-depressed in lateral view. Snout rounded in dorsal view, truncate in lateral view. Nostrils absent in early development stages. Eyes lateral. Oral disc lacking keratinized structures, rounded lip flaps over and covering the oral opening. Marginal papillae absent. Spiracle long, tubular, ventrally positioned, extending posteroventrally reaching and overlapping the vent tube. Vent tube medial. Dorsal fin originating at tail-body junction, dorsal and ventral fins arched. Tail length about 60% of total length, tail tip acute.

*Stereocyclops* Cope, 1870

Species occurring in the region. *Stereocyclops incrassatus* Cope, 1870 (Figure 9F): Wogel et al. (2000), municipality of Saquarema, state of Rio de Janeiro, Brazil.

Specimens examined. *Stereocyclops incrassatus*: MUFAL 10126 (n = 9, stage 30–31), municipality of Marechal Deodoro, state of Alagoas, Brazil.

Characteristics: Body rounded in dorsal view, triangular-depressed in lateral view. Snout rounded in dorsal view, truncate in lateral view. Nostrils circular, located between eyes and tip of snout. Eyes dorsal. Oral disc ventral, emarginate laterally. Marginal papillae arranged ventrolaterally, with a wide dorsal gap. LTRF 2(2)/3(1). Spiracle sinistral. Vent tube dextral. Dorsal fin originating on posterior third of the body, dorsal fin arched and ventral fin slightly arched. Tail length approximately 50% of total length, tail tip acute.

*Family Odontophrynidae*

*Macrogenioglottus* Carvalho, 1946

Species occurring in the region. *Macrogenioglottus alipioi* Carvalho, 1946 (Figure 9G): Abravaya & Jackson (1978), municipality of Santa Teresa, state of Espírito Santo, Brazil; Lisboa et al. (2011), municipality of Maceió, state of Alagoas, Brazil.

Specimens examined. *Macrogenioglottus alipioi*: MUFAL 10166 and 12468 (n = 7, stages 31–34), municipality of Maceió, and MUFAL 13952 (n = 3, stages 30–37) municipality of Satuba; both from the state of Alagoas, Brazil.

Characteristics: Body rounded in dorsal view and globular in lateral view. Snout rounded in dorsal view, truncate in lateral view. Nostrils circular, located between eyes and tip of snout. Eyes dorsal. Oral disc ventral, emarginate laterally. Marginal papillae arranged ventrolaterally, with a wide dorsal gap. LTRF 2(2)/3(1). Spiracle sinistral. Vent tube dextral. Dorsal fin originating on posterior third of the body, dorsal fin arched and ventral fin slightly arched. Tail length approximately 50% of total length, tail tip acute.

*Odontophrynus* Reinhardt and Lütken, 1862

Species occurring in the region. *Odontophrynus carvalhoi* Savage & Cei, 1965 (Figure 9H): Caramaschi (1979), municipality of Maracás, state of Bahia, Brazil; Santos et al. (2017), municipalities of São Domingos and Sítio d’Abadia; both from the state of Goiás, Brazil; Costa et al. (2017), municipality of Triunfo, state of Pernambuco, Brazil.
Specimens examined. *Odontophrynus carvalhoi*: MUFAL 10717 (n = 15, stages 30–40), municipality of Triunfo, state of Pernambuco, Brazil.

Characteristics: Body elliptical in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils reniform, closer to eyes than to tip of snout. Eyes dorsal. Oral disc anteroventral, emarginate laterally. Marginal papillae arranged ventrolaterally, with a wide dorsal gap. LTRF 2/3(1). Spiracle sinistral. Vent tube dextral. Dorsal fin originating at posterior portion of body, dorsal fin arched and ventral fin parallel to longitudinal axis of tail. Tail length about 60% of total length, tail tip acute.

*Proceratophrys* Miranda-Ribeiro, 1920

Species occurring in the region. *Proceratophrys cristiceps* (Müller, 1883) (Figure 10A): Vieira et al. (2007b), municipality of São João do Cariri, state of Paraíba, Brazil. *Proceratophrys renalis* (Miranda-Ribeiro, 1920) (Figure 10B): Nascimento et al. (2010), municipality of Maceió, state of Alagoas, Brazil.

Specimens examined. *Proceratophrys cristiceps*: CHUFPB 28093 (n = 15, stages 35–38), municipality of Macaíba, state of Rio Grande do Norte, Brazil. *Proceratophrys renalis*: MUFAL 12501 (n = 16, stages 30–39), municipality of Murici, state of Alagoas, Brazil.

Characteristics: Body ovoid in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils reniform, closer to eyes than to tip of snout. Eyes dorsal. Oral disc ventral, emarginate laterally. Marginal papillae arranged ventrolaterally, with a wide dorsal gap. LTRF 2(2)/3(1). Spiracle sinistral. Vent tube dextral. Dorsal fin originating at posterior portion of body, dorsal fin arched and ventral fin parallel to longitudinal axis of tail. Tail length about 60% of total length, tail tip acute.

**Family Phyllomedusidae**

*Hylomantis* Peters, 1873 “1872”

Species occurring in the region. *Hylomantis granulosa* (Cruz, 1989) (Figure 10C): Nascimento & Skuk (2007), municipality of Maceió, state of Alagoas, Brazil.

Specimens examined. *Hylomantis granulosa*: MUFAL 13948, MUFAL 13950 (n = 15, stages 30–37), municipality of Satuba, state of Alagoas, Brazil.

Characteristics: Body elliptical-elongated in dorsal view, triangular-obtuse in lateral view. Snout oval in dorsal and lateral view. Nostrils circular, located anteriorly, closer to tip of snout than to eyes. Eyes lateral. Oral disc anterior, posterior margin visible in dorsal view, not emarginate. Marginal papillae arranged lateroventrally, with a wide dorsal gap. LTRF 2(2)/3. Spiracle located ventrolaterally. Vent tube dextral. Dorsal fin originating at tail-body junction, dorsal fin parallel to tail musculature and ventral fin arched. Tail length about 60% of total length, tail tip acute with flagellum.

*Pithecopus* Cope, 1866

Species occurring in the region. *Pithecopus nordestinus* (Caramaschi, 2006) (Figure 10D): Cruz (1982), municipality of Itajibá, state of Bahia, Brazil.

Specimens examined. *Pithecopus nordestinus*: MUFAL 12457 (n = 16, stages 30–40), municipality of Junqueiro; MUFAL 12464 (n = 16, stages 27–31), municipality of Teotônio Vilela, and MUFAL 12483 (n = 15, stages 30–39), municipality of Igarã; both from the state of Alagoas, Brazil; CHUFPB 28074–79 (n = 19, stage 37), municipality of Maceió, state of Rio Grande do Norte, Brazil.

Characteristics: Body elliptical-elongated in dorsal view, triangular-obtuse in lateral view. Snout rounded in dorsal view, truncate in lateral view. Nostrils circular, closer to tip of snout than to eyes. Eyes lateral. Oral disc anterior, not emarginate. Marginal papillae arranged ventrolaterally, with a wide dorsal gap. LTRF 2(2)/3(1). Spiracle midventral. Vent tube dextral. Dorsal fin originating on body, dorsal fin parallel to longitudinal axis of tail and ventral fin arched. Tail length about 60% of total length, tail tip acute with flagellum.

**Family Pipidae**

*Pipa* Laurenti, 1768

Figure 10. Lateral, dorsal and ventral views (scale = 3mm) and oral disc (scale = 1mm) of tadpoles occurring in the north of the Atlantic Forest.

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http://www.scielo.br/bn
Species occurring in the region. *Pipa carvalhoi* (Miranda-Ribeiro, 1937) (Figure 10E): Sokol (1975), municipality of Garanhuns, state of Pernambuco, Brazil.

Specimens examined. *Pipa carvalhoi*: MUFAL 12485 (n = 15, stages 51–58), municipality of Igaci, state of Alagoas, Brazil; MZFS 379 (n = 15, stages 53–58), municipality of Ibiricu, state of Bahia, Brazil.

Characteristics: Body rounded in dorsal view, triangular-boat shape in lateral view. Snout rounded in dorsal view, truncate in lateral view. Nostrils elliptical, closer to tip of snout than to eyes. Eyes lateral. Oral disc triangular, lacking keratinized structures. Marginal papillae absent. Two ventral spiracles. Vent tube medial. Dorsal fin originating on tail, dorsal fin parallel to longitudinal axis of tail and ventral fin arched. Tail length approximately 65% of total length, tail tip acute with flagellum.

**Family Ranidae**

*Lithobates* Fitzinger, 1843

Species occurring in the region. *Lithobates palmipes* (Spix, 1824) (Figure 10F): Breder (1946), Panama; Kenny (1968), Trinidad; Rada-de-Martínez (1990), Venezuela.

**Key to tadpoles found in the northern Atlantic Forest (Portuguese version available in Supplementary Material 2)**

1. Oral disc lacking keratinized structures (jaws and/or labial teeth) ................................................................. 2
2. Oral disc with keratinized structures .................................................................................................................. MICROHYLIDAE 11
2a. (1a) One spiral (Fig. 11a) ................................................................................................................................. 2
2b. Two spiracles (Fig. 11b) ..................................................................................................................................... PIPIDAE: *Pipa carvalhoi* (Fig. 10e)
3. (1b) Eyes positioned laterally (Fig. 11c) ........................................................................................................... 4
3a. (2a) Eyes positioned laterally (Fig. 11c) ........................................................................................................... 4
3b. Eyes positioned dorsally (Fig. 11f) .................................................................................................................. 5
4a. (3a) Spiral ventral (Fig. 11c) ............................................................................................................................ 5
4b. Spiral ventral (Fig. 11d) ....................................................................................................................................... HYLIDAE 15
5. (3b) Upper jaw sheath with a medial reentrance (Fig. 11n[i]) ............................................................................ AROMOBATIDAE: *Allobates olfersioides* (Fig. 3a)
5a. Upper jaw sheath arch-shaped (Fig. 11n[i]) or absent ...................................................................................... 6
5b. Oral disc laterally emarginate (Fig. 11n[i]) or modified in a single dermal fold on anterior lip (Fig. 11ab) .................................................................................................................................................. 7
6. Oral disc not laterally emarginate or modified in two dermal folds on anterior lip (Fig. 11k) .................... 10
7a. (6a) Three or four anterior labial teeth rows ................................................................................. RANIDAE: *Lithobates palmipes* (Fig. 10f)
7b. Less than three anterior labial teeth rows or anterior labial teeth rows absent ........................................ 8
8a. (7b) Marginal papillae on anterior lip with a single and broad medial interruption (Fig. 11v) or marginal papillae completely absent (Fig. 11ab) .......................................................................................................................... 8
8b. Marginal papillae on posterior lip with two to three interruptions or without interruption ...... 9
9a. (8b) Marginal papillae on posterior lip without interruption, vent tube dextral (Fig. 11ag) ................ ODONTOPHRYNIDAE 58
9b. Only one or none of the characteristics above ...................................................................................... LEPTODACTYLIDAE 44
10a. (6b) Oral disc not emarginated, anterior margin of oral disc totally fused with body wall LEPTODACTYLIDAE: *Leptodactylus* 48
10b. Only one or none of the characteristics above ...................................................................................... HYLIDAE 31
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12b. Labial flaps crown shaped (Fig. 11r) ........................................................................................................... 13
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13b. Anterior portion of tail musculature thin without opaque fins (Fig. 9f), tail tip acute with flagellum Stereocyclops incrassatus (Fig. 9f) .................................................................................................................................................. 13
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14b. Posterior lip not visible in dorsal view ........................................................................................................ Pithecopus nordestinus (Fig. 10d)
15a. (4b) Three or less labial teeth rows on oral disc ............................................................................. Dendropsophus 16
15b. More than three labial teeth rows on oral disc ...................................................................................... 16
16a. (15a) Maximum ventral fin higher than tail musculature height, body triangular in lateral view (Fig. 2e) Dendropsophus minutus (Fig. 5g)
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17b. Row of marginal papillae absent (Fig. 11i)…………………………………………………………………………………………………………………………...21
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20b. Tail with large black cross-shaped bars or completely pigmented, black cross-shaped bars absent on body (Fig. 5a)……………………………………..20
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23b. Less than six labial teeth rows on oral disc ……………………………………………………………………………………………………………………24
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29a. (27b) Maximum body height in the region of the spiracle aperture, ventral fin originating at posterior body region, shortly before vent tube insertion (Fig. 11i)………………………………………………………………………………………………………………30
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40a. (33b) Three posterior labial teeth rows, posterior lip concave when closed (Fig. 11z) ................................... Ololygon 41

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41a. (40a) Nostrils dorsal, located closer to eyes than to snout, second anterior labial teeth row without medial gap, tail with homogeneous light coloration (Fig. 6a) ............................................................... Ololygon skuki (Fig. 6a)

41b. Nostrils dorsolaterally, located closer to snout than to eyes, second anterior labial teeth row with medial gap, tail with large dark brown bar in the end portion (Fig. 5h) ........................................ Phyllodytes melanodactyla (Fig. 5h)

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43b. Body ovoid in dorsal view (Fig. 2c), dorsal fin originating at tail-body junction (Fig. 11i), four labial teeth rows on the posterior lip.......................... Phyllodytes acuminatus (Fig. 6b)

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53a. (49b) Oral disc with a pair of ventral folds when closed, eye diameter larger than the distance from nostrils to the snout ........................................................................................................... Leptodactylus natalensis (Fig. 8d)

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54a. (8a) Presence of marginal papillae ...................................................................................................... Rhinella 55

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55a. (54a) Third posterior row of labial teeth short, with length less than half of the length of second posterior row .......... Rhinella granulosa (Fig. 3d)

55b. Posterior labial teeth rows equal in length ...........................................................................................................56

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Figure 11. Morphological characteristics used to larval characterizations and in the taxonomic key. Details of characteristics are mentioned in the taxonomic key.
Discussion

The great morphological diversity of tadpoles is related to the large number of species, genera and families of anurans occurring in the Atlantic Forest north of the São Francisco River, as well as to the diversity of habitats and habits of their tadpoles. The tadpoles of the 63 species from the northern region of the Atlantic Forest with known larval phase represent almost all guilds (sensu Altig & McDiarmid 1999; Rossa-Feres et al. 2004) with diverse feeding habits such as sectarius, raptors, carnivorous, macrophages and endotrophics (Dubeux et al. 2019). Most tadpoles develop in lentic or lotic environments, but five in phytotelmata (Froelichius pernambucensis and Simões (CHUFPE), and M. Kokubum (UFCG), R. Abreu (UFBA), and R. Costa and C. Mira-Mendes (UESC) for photographs; L. Weber (UFSB) for his help in obtaining material analyzed; G. Rodrigues (U.PORTO), I. Santos, B. Lisboa (UFPE), A. Valencia-Aguilar (UNESP), B. Vilela (UFBA), G. Ruano-Fajardo and G. Skuk (in memoriam) for their helping in advancing the state of knowledge of tadpoles in the state of Alagoas. We thank all those who volunteered to test the identification key presented here and certainly contributed to this study. We also thank the editor M. Napoli (UFBA) and the two reviewers for the valuable suggestions that contributed to the improvement of this work. DCRF and TM are grateful to the project “Tadpoles from Brazil” (Edital SISBIOTA, Process CNPq 563075/2010-4 and FAPESP 2010/52321-7). MJMD thanks Fundação de Amparo a Ciência e Tecnologia do Estado de Pernambuco - FACEPE (IBPG-1117-2.04/19) for financial support. DCRF thanks Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq for the research fellowship (302328/2017-3). TM thanks CNPq (309904/2015-3) for financial support. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - 8882.440382/2019-01.

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Supplementary Material

The following online material is available for this article:

Supplementary Material 1 - List of anuran amphibians recorded in the northern region of the Atlantic Forest.

Supplementary Material 2 - Chave de identificação para os girinos encontrados no norte da Mata Atlântica.
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