















## 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, Sherrat 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 & Maltchink 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, Hemiphractidae, 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 olfersioides*, *Adelophryne baturitensis*, *Chiasmocleis alagoana*, *Crossodactylus dantei*, *Hylomantis granulosa*, *Phyllodytes gyrinaethes*, and *Physalaemus caete*), 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

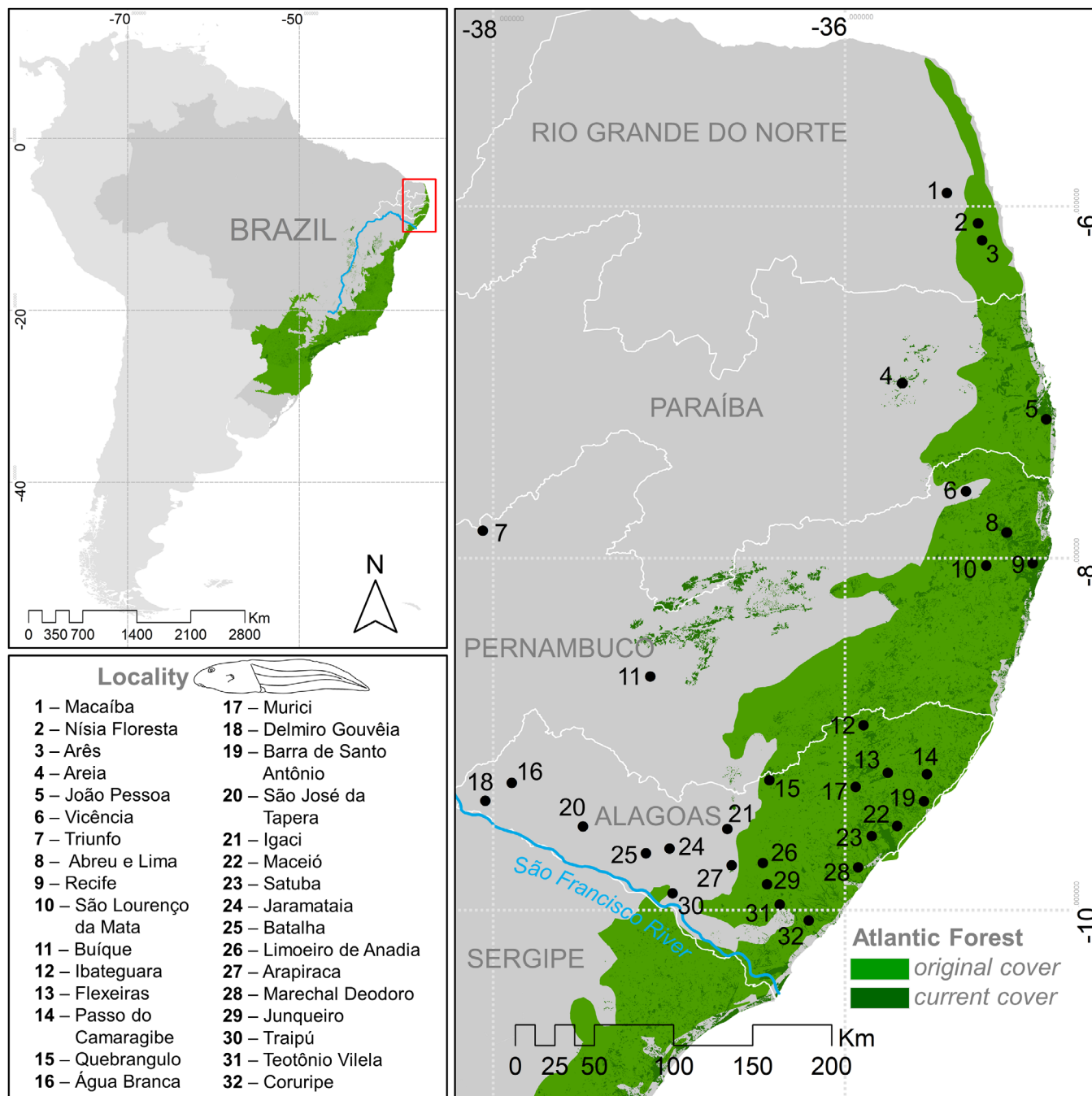
We analyzed 1,042 tadpoles collected from 32 localities (Figure 1) and encompassing 63 species from 28 genera occurring in the northern region of the Atlantic Forest (north of the São Francisco River). Species of three genera occurring in the region, *Pristimantis* Jiménez-de-la-Espada, 1870 (Craugastoridae), *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 dantei* Carcerelli & Caramaschi, 1993 (Hylodidae), *Leptodactylus ochraceus* Lutz, 1930 (Leptodactylidae), and those of the hylids *Boana exastis* (Caramaschi & Rodrigues, 2003), *Ololygon muriciensis* 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 (DZSJR), Coleção Herpetológica do Museu de História Natural da Universidade Federal de Alagoas (MUFAL), Coleção Herpetológica do Museu de Zoologia da Universidade Estadual de Santa Cruz (MZUESC), Coleção Herpetológica do Museu de Zoologia da Universidade Estadual de Feira de Santana (MZFS), Coleção Herpetológica da Universidade Federal da Paraíba (CHUFPB), Coleção Herpetológica da Universidade Federal de Pernambuco (CHUFPE), and Laboratório de Herpetologia da Universidade Federal de Campina Grande (LHUFPG). 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, Laufer 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

Identification key of Atlantic Forest's tadpoles



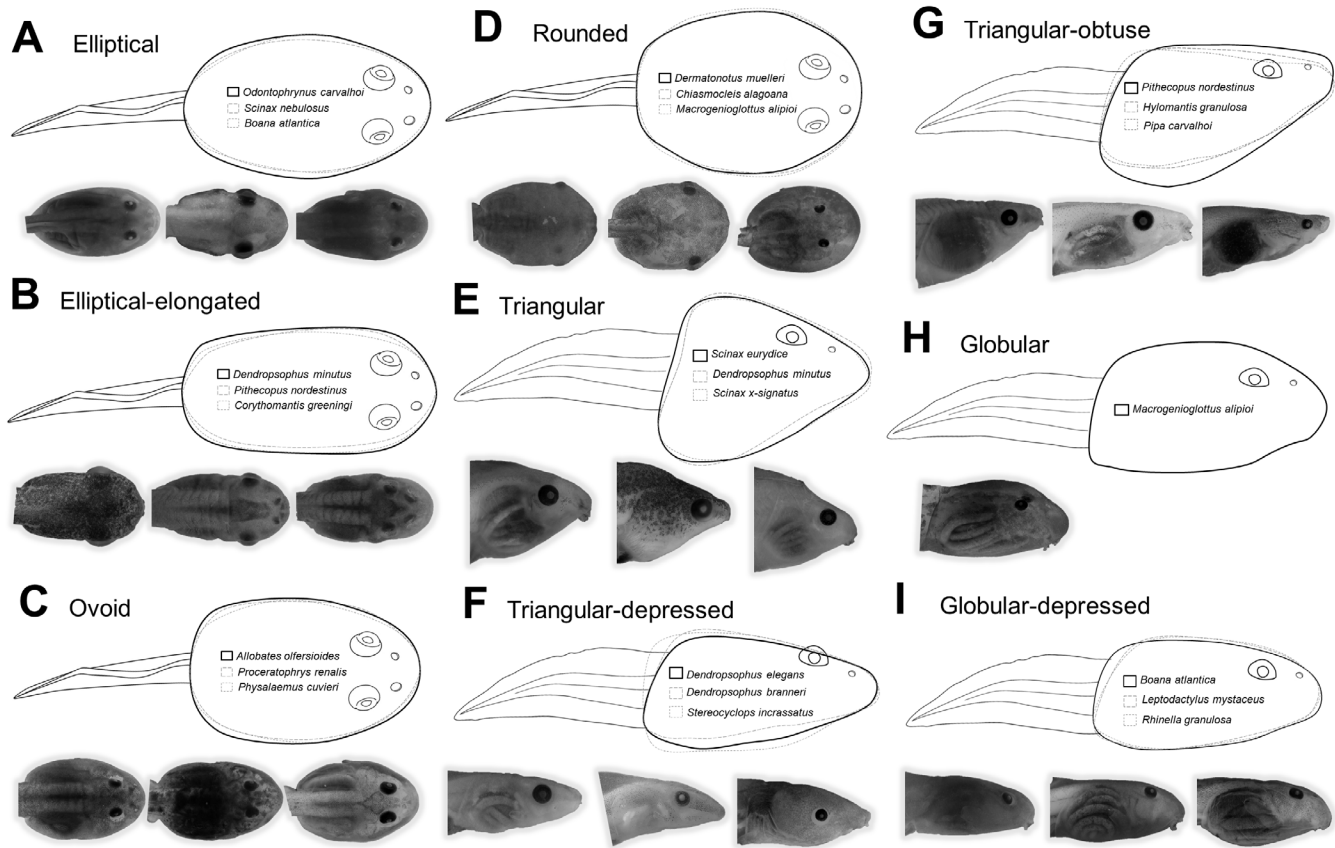
**Figure 1.** Map of the study area, northern portion of the Atlantic Forest located north of the São Francisco River. Black circles correspond to the locations from which the analyzed tadpoles came from. Inset map: South America.

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



**Figure 2.** Standardization proposal of morphogeometric characteristics used for larval characterizations and in the taxonomic key.

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 snout than to eyes. 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.

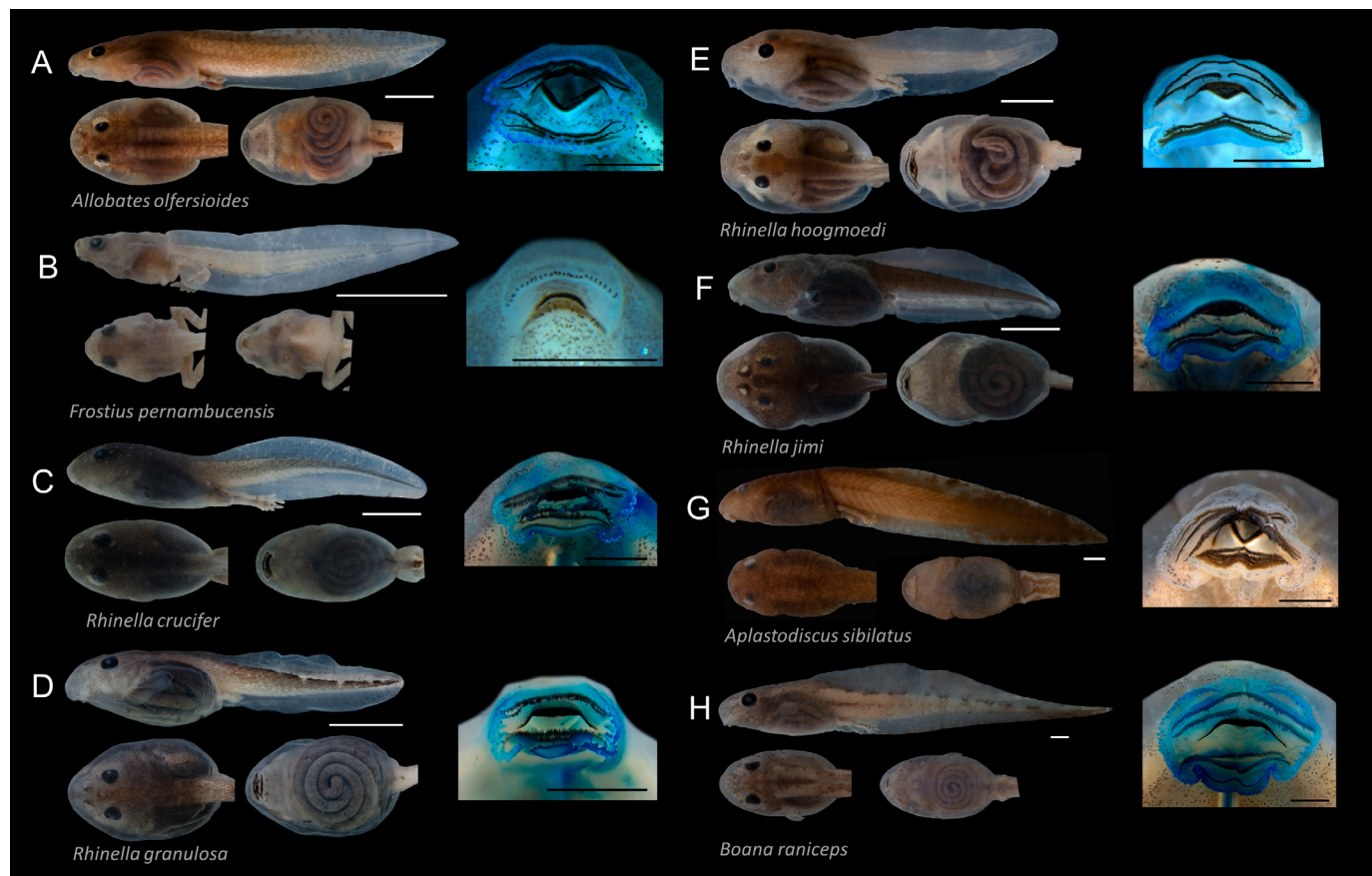
Specimens examined. *Frostius pernambucensis*: MUFAL 14572 (n = 5, stages 41–42), municipality of Murici, state of Alagoas, Brazil.

Characteristics: Body ovoid in dorsal view, globular-depressed in lateral view. Snout oval in dorsal view, truncate in lateral view. 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,

## Identification key of Atlantic Forest's tadpoles



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

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 jimi* (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 jimi*: 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): Kolenc 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

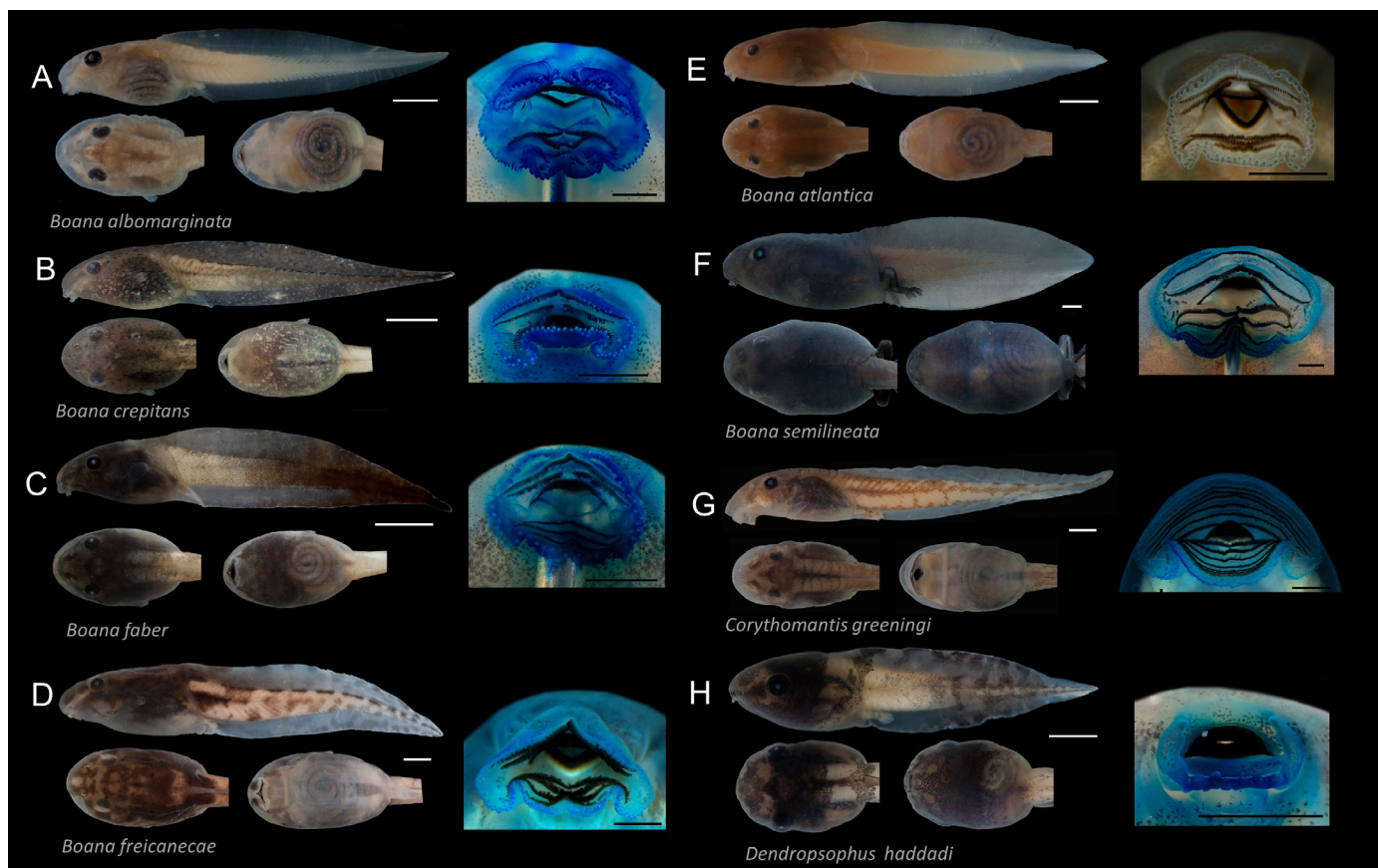
Rio de Janeiro (Grumari's administrative region) and Itaguaí; both from the state of Rio de Janeiro, Brazil, and municipality of Recife, state of Pernambuco, Brazil. *Boana crepitans* (Wied-Neuwied, 1824) (Figure 4B): Kenny (1968), Trinidad; Lynch (2006), Colombia; Casal & Juncá (2008), municipality of Feira de Santana, state of Bahia, Brazil. *Boana faber* (Wied-Neuwied, 1821) (Figure 4C): Cei (1980) and Kolenc et al. (2008), Argentina. *Boana pulchella* species group (Faivovich et al. 2005) – *Boana freicanecae* (Carnaval & 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; CHUFPPB 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; CHUFPPB 28471–72 (n = 4, stages 26–31), municipality of João Pessoa, state of Paraíba, Brazil; CHUFPPB 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)/4(1) or 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)/3(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(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): Juncá 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). 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**

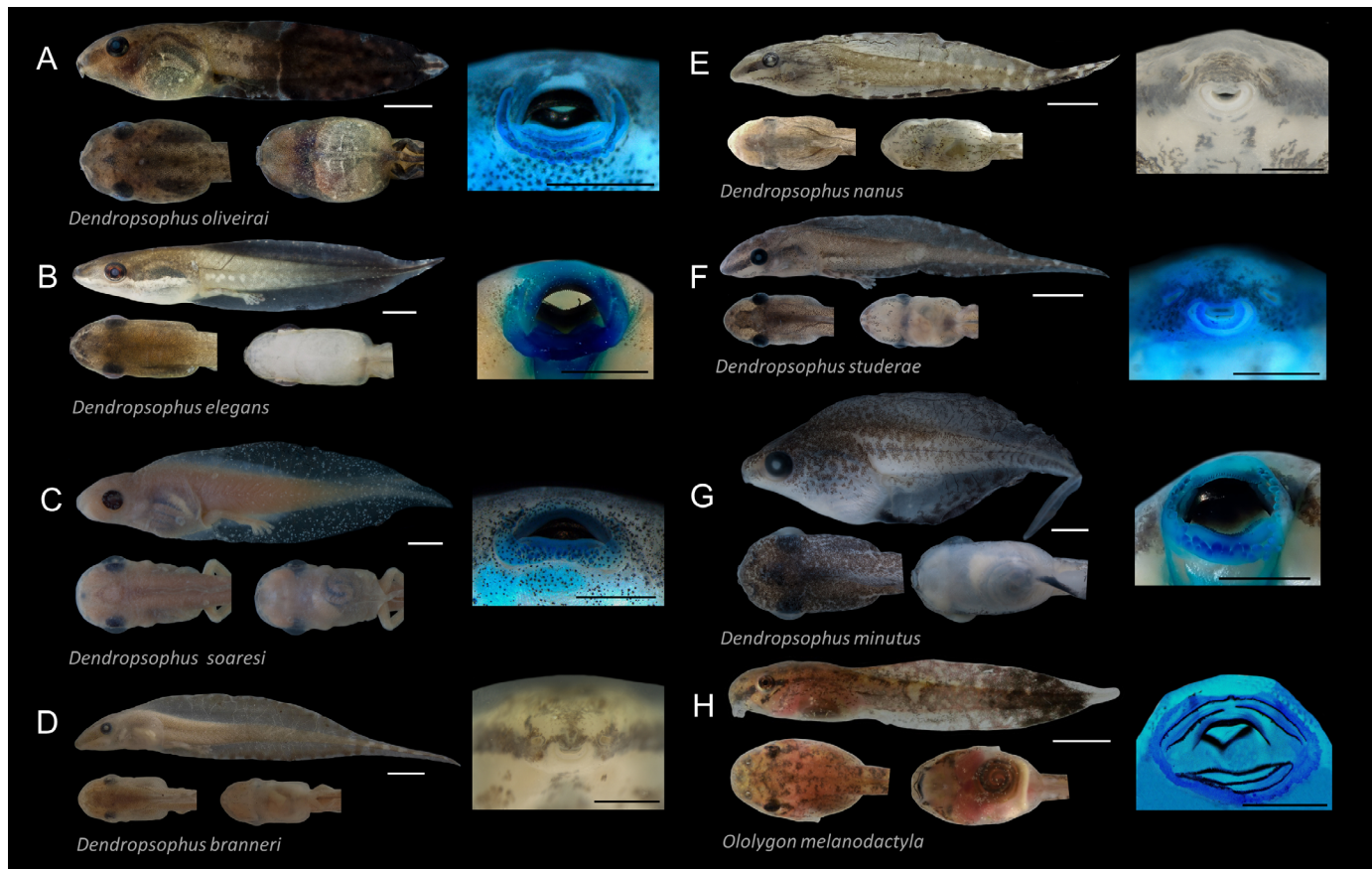
Species occurring in the region. *Dendropsophus decipiens* species group (Faivovich et al. 2005) – *Dendropsophus haddadi* (Bastos & Pombal, 1996) (Figure 4H): Abreu et al. (2013), municipality of Mata de São João, state of Bahia, Brazil. *Dendropsophus oliveirai* (Bokermann, 1963) (Figure 5A): Pugliese et al. (2000), municipality of Quebrangulo, state of Alagoas, Brazil. *Dendropsophus leucophyllatus* species group (Faivovich et al. 2005) – *Dendropsophus elegans* (Wied-Neuwied, 1824) (Figure 5B): Gomes & Peixoto (1991a), municipalities of Maricá and Magé; both from the state of Rio de Janeiro, Brazil. *Dendropsophus marmoratus* species group (Faivovich et al. 2005) – *Dendropsophus soaresi* (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 studerae* (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; Vizotto (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 Ibatiguara, 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 Limoeiro de Anadia, 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 soaresi*: 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 studerae*: MUFAL 15459–60 (n = 4, stages 37–38), municipality of Quebrangulo, state of Alagoas, Brazil.

Characteristics: *Dendropsophus decipiens* species group – Body elliptical 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 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.

*Dendropsophus leucophyllatus* 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. 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 tail-body



**Figure 5.** Lateral, dorsal and ventral views (scale = 3mm) and oral disc (scale = 1mm) of tadpoles occurring in the north of the Atlantic Forest.

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.

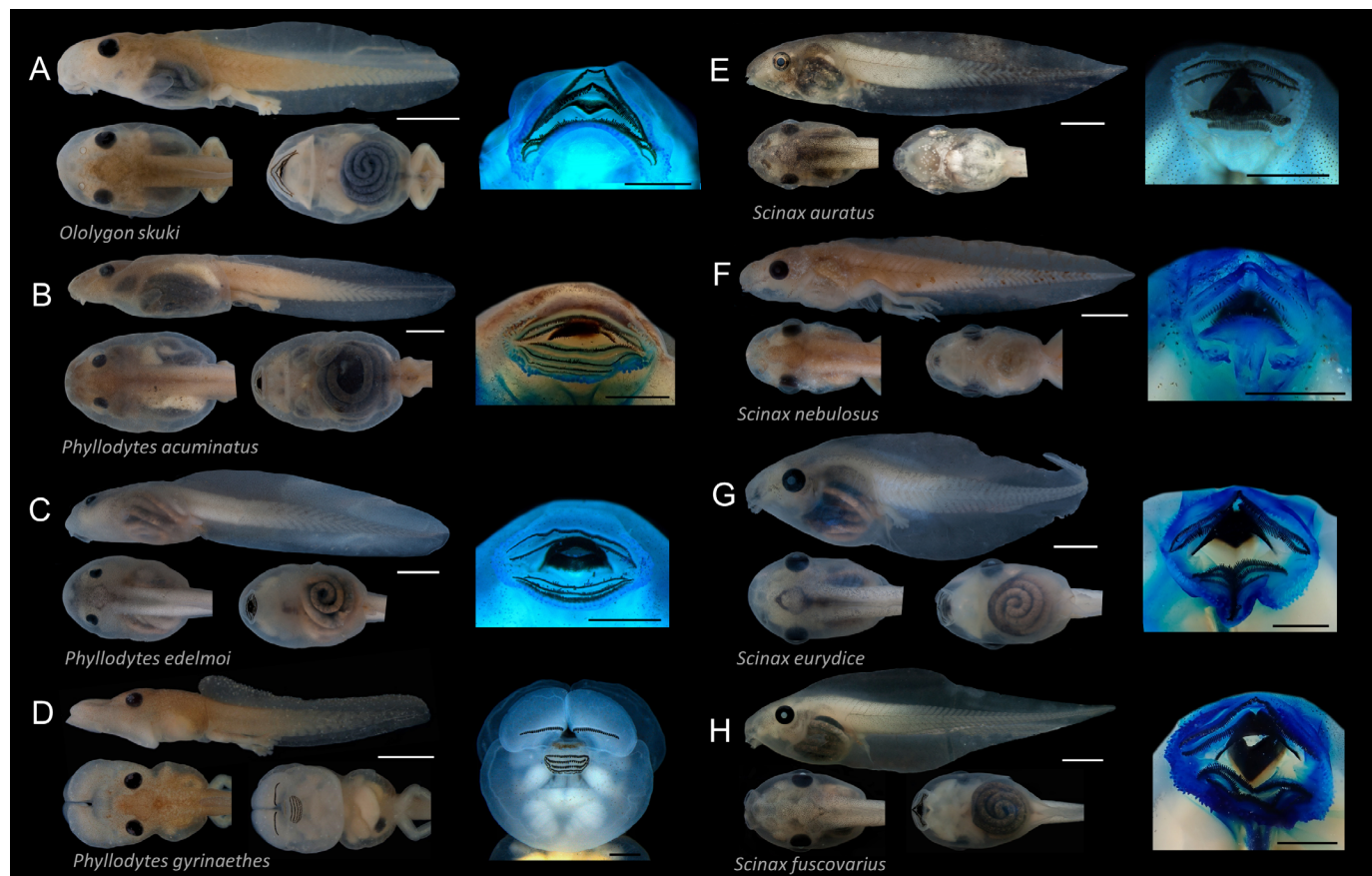
#### *Ololygon* Fitzinger, 1843

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

Specimens examined. *Ololygon skuki*: MUFAL 10200, 10161, 11041, 11052, 11062, 11085 (n = 17, stages 31–40), municipality of Maceió, state of Alagoas, Brazil. *Ololygon 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 rounded 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





**Figure 6.** Lateral, dorsal and ventral views (scale = 3mm) and oral disc (scale = 1mm) of tadpoles occurring in the north of the Atlantic Forest.

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 brevisrostris* 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.

Specimens examined. *Phyllodytes acuminatus*: MUFAL 8384 (n = 11, stages 30–40), municipality of Buíque, state of Pernambuco, Brazil. *Phyllodytes brevisrostris*: exceptionally for this species, the morphological data were obtained from the literature because specimens were not available in the visited scientific collections (UFPB 4881, n = 40, stage 35), municipality of Cruz do Espírito Santo, state of Paraíba, Brazil. *Phyllodytes edelmoi*: MUFAL 3770 (n = 3, stage 40), municipality of Maceió, state of Alagoas, Brazil. *Phyllodytes gyrinaethes*: MUFAL 13689 (n = 3, stage 30), municipality of Murici, state of Alagoas, Brazil.

Characteristics: Body ovoid or elliptical in dorsal view, globular-depressed in lateral view. Snout rounded in dorsal view, sloped in lateral view. Nostrils circular, closer to tip of snout than to eyes. Eyes dorsal. Oral disc ventral, not emarginate. Marginal papillae arranged ventrolaterally, with a wide dorsal gap, absent in *P. gyrinaethes*. LTRF 2(2)/4[5] or 1(1)/5, the latter only for *P. gyrinaethes*. Spiracle sinistral. Vent tube dextral. Dorsal fin originating at the end of body or at tail-body junction, dorsal fin arched or parallel to longitudinal axis of tail and ventral fins parallel to longitudinal axis of tail. Tail length 65% of total length, tail tip rounded.

Notes: Morphologically, *P. gyrinaethes* differs from all congeners by having a bell-shaped body in dorsal view, wider posteriorly and with lateral reentrances in the midbody; snout flat with a deep indentation at the anterior margin in dorsal view. Peixoto et al. (2003) reported specimens of *P. edelmoi* with LTRF 2(2)/5[6], while the specimens analyzed in the present study had LTRF 2(2)/5.

***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

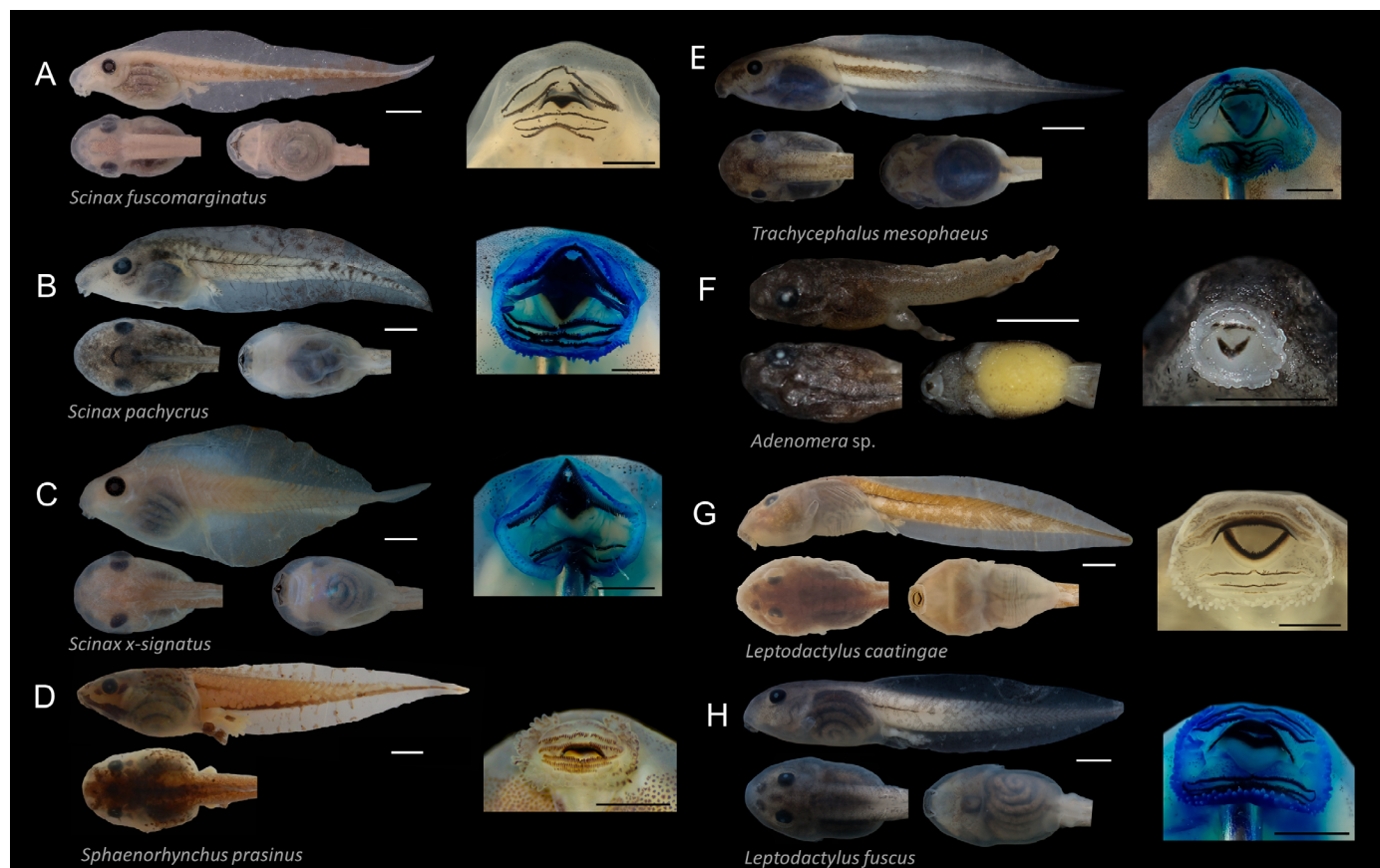
(Faivovich 2002), see characteristics; Figure 6E): Alves et al. (2004), municipality of Quebrangulo, state of Alagoas, Brazil. *Scinax nebulosus* (Spix, 1824) (Figure 6F): Gomes et al. (2014), municipality of Cabo de Santo Agostinho, state of Pernambuco, Brazil. Species of the *Scinax* unassigned to 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 7A): Vizotto (1967), state of São Paulo, Brazil. *Scinax pachycrus* (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 fuscovarius*: 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 nebulosus*: MUFAL 3785 (n = 2, stages 30–40), municipality of Maceió; MUFAL 13912 (n = 5, stages 37–38), 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 7.** Lateral, dorsal and ventral views (scale = 3mm) and oral disc (scale = 1mm) of tadpoles occurring in the north of the Atlantic Forest.

sinistral. Vent tube dextral. Dorsal fin originating at the middle or end of body, dorsal and ventral fins arched. Tail length about 70% of total length, tail tip acute.

***Sphaenorhynchus*** Tschudi, 1838

Species occurring in the region. *Sphaenorhynchus prasinus* Bokermann 1973 (Figure 7D): Bokermann (1973), municipality of Ilhéus, 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 Ilhéus, 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 and ventral fin slightly arched. Tail length about 60% 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 and ventral fins slightly arched. Tail length nearly 70% of total length, tail tip acute, with flagellum.

**Family Leptodactylidae**

***Adenomera*** Steindachner, 1867

Species occurring in the region. *Adenomera* aff. *hylaedactyla* (Cope, 1868): Kokubum & de-Souza (2008), municipality of Rio Branco, state of Acre, Brazil; Menin et al. (2009), municipality of Manaus, state of Amazonas, Brazil.

Specimens examined. *Adenomera* sp.: LHUFCG 0110 (n = 1, stage 36; Figure 7F), northeastern Brazil. The populations occurring in the Atlantic Forest domain are probably an undescribed taxon and there are

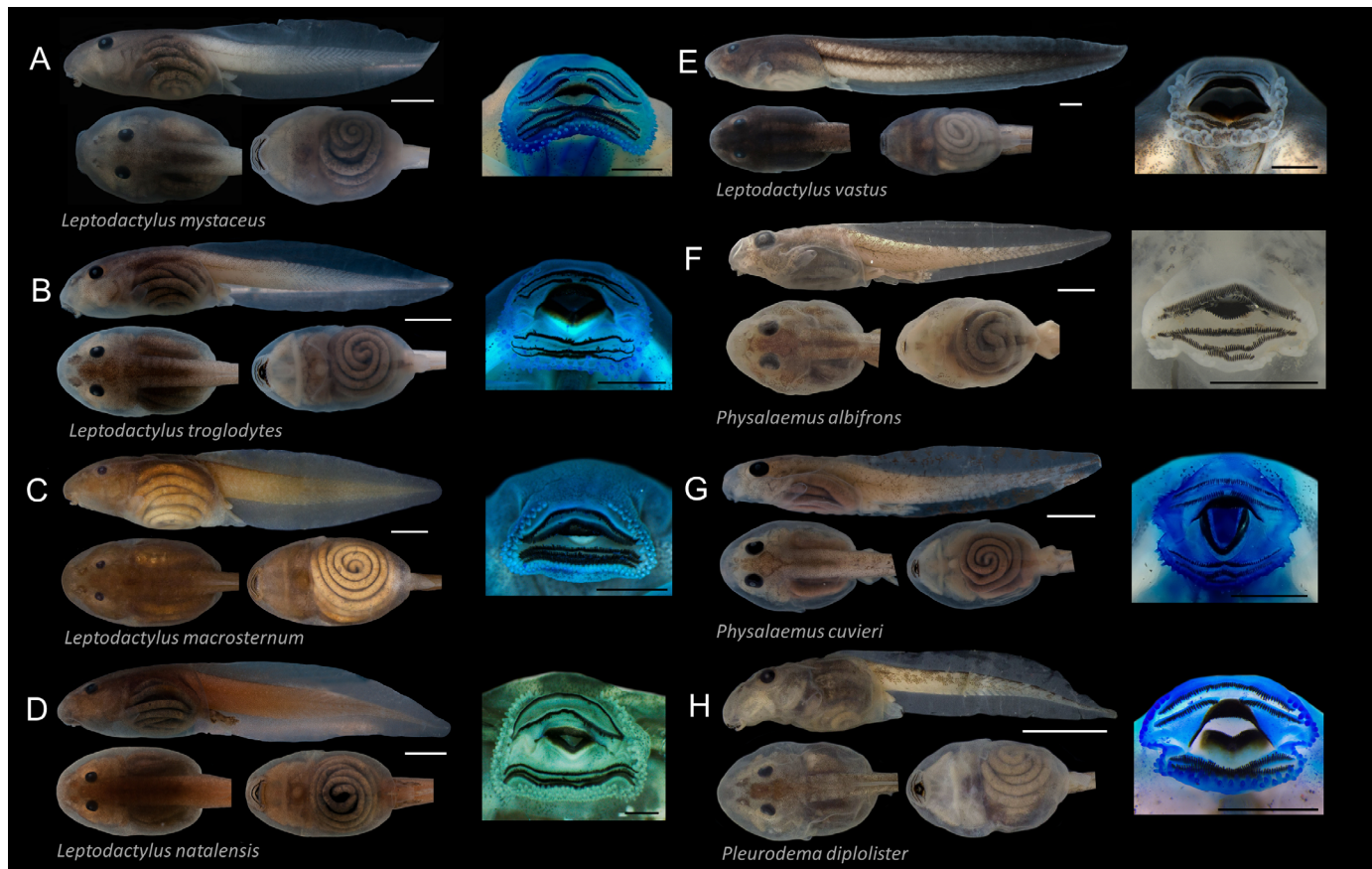
no tadpole specimens available, so they were not included in the key. However, due to the phylogenetically conserved morphology of these endotrophic tadpoles, we present here a general characterization for the genus based on specimens obtained in the Cerrado biome.

Characteristics: Body ovoid in dorsal view, oval-depressed in lateral view. Snout rounded in dorsal view, oval in lateral view. Nostrils circular, located closer to tip of snout than to eyes. Eyes dorsal. Oral disc ventral, not emarginate. Marginal papillae with broad dorsal gap. LTRF 0/0. No spiracle. Vent tube medial. Dorsal fin originating at tail-body junction, dorsal fin and ventral fin parallel to longitudinal axis of tail. Tail length approximately 65% 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), Equador; Hero (1990), municipality of Manaus, state of Amazonas, Brazil; Heyer (1978), Ecuador. *Leptodactylus troglodytes* Lutz, 1926 (Figure 8B): Cascon & 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 melanonotus* species group (de Sá et al. 2014) – *Leptodactylus natalensis* Lutz, 1930 (Figure 8D): Oliveira & Lírio-Júnior (2000), municipality of São Cristóvão, state of Sergipe, Brazil; Dubeux 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*: CHUFPPB 27232, 28001, 28217 (n = 20, stage 36), municipality of Macaíba, state of Rio Grande do Norte, Brazil. *Leptodactylus fuscus*: CHUFPPB 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; CHUFPPB 28002–5 (n = 20, stages 32–34), municipality of Macaiba, 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*: MUFAL12465 (n = 10, stages 36–37), municipality of Teotônio Vilela, state of Alagoas, Brazil. *Leptodactylus troglodytes*: CHUFPPB 28071 (n = 8, stages 35–39), municipality of Macaiba, and CHUFPPB 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;



**Figure 8.** Lateral, dorsal and ventral views (scale = 3mm) and oral disc (scale = 1mm) of tadpoles occurring in the north of the Atlantic Forest.

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 slightly rounded.

*Leptodactylus melanonotus* 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 slightly arched. Tail length approximately 60% of total length, tail tip acute.

*Leptodactylus pentadactylus* species group – Body oval, elongated in dorsal view, globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils circular, located almost midway between the eyes and the snout tip. Eyes dorsal. Oral disc anteroventral, not emarginate, anterior margin of oral disc totally fused with body wall. Marginal papillae arranged ventrolaterally, with a wide dorsal gap. LTRF 1/2(1). 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 caete* 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.

Specimens examined. *Physalaemus albifrons*: CHUFPPB 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 this species, the morphological data were obtained from the literature because specimens were not available in the visited scientific collections (MNRJ 18280, n = 1, stage 28), municipality of Passo do Camaragibe, state of Alagoas, Brazil. *Physalaemus cuvieri*: MUFAL 10208 (n = 11, stages 34–40), municipality of Coruripe, state of Alagoas, Brazil; CHUFPPB 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, narrow ventromedial 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*: CHUFPPB 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*: CHUFPPB 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*: CHUFPPB 28021–22 (n = 20, stages 36–40), municipality of Macaíba; CHUFPPB 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.

##### ***Dermatonotus* Méhely, 1904**

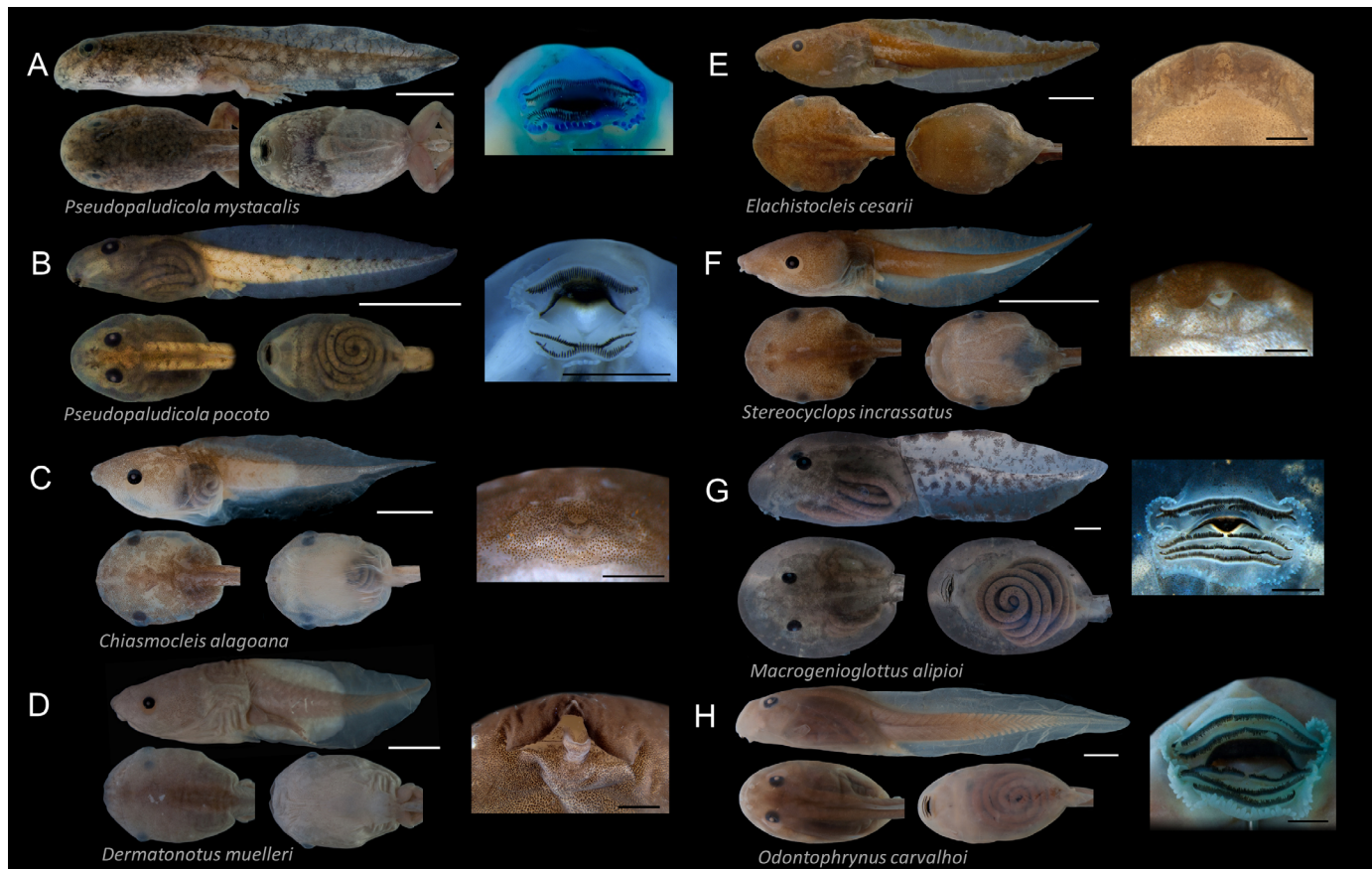
Species occurring in the region. *Dermatonotus muelleri* (Boettger, 1885) (Figure 9D): Cei (1980) and Lavilla (1992), Argentina; Vizotto (1967), state of São Paulo, Brazil; Schulze et al. (2015), Bolivia.

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; CHUFPPB 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.



**Figure 9.** Lateral, dorsal and ventral views (scale = 3mm) and oral disc (scale = 1mm) of tadpoles occurring in the north of the Atlantic Forest.

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 absent in early development stages. Eyes lateral. Oral disc lacking keratinized structures, square 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 slightly arched. Tail length about 60% of total length, tail tip acute with flagellum.

**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, oval 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 & Ceil, 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

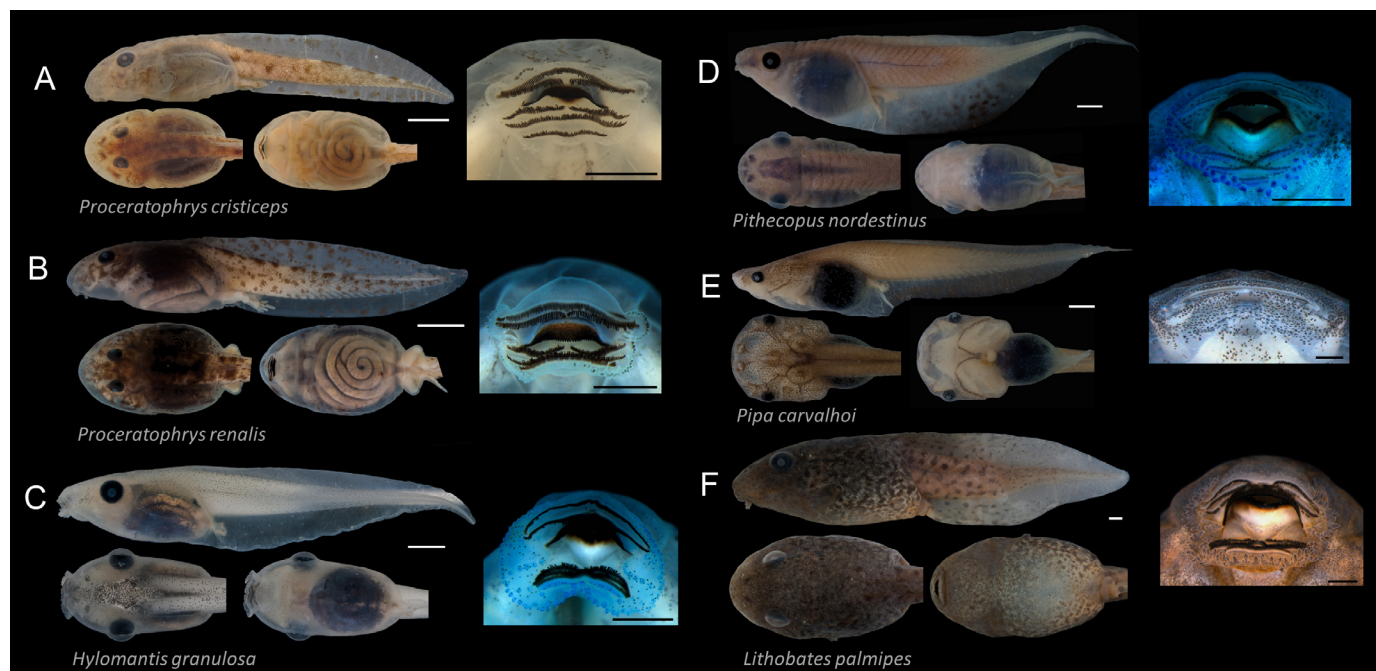
Species occurring in the region. *Pithecopus nordestinus* (Caramaschi, 2006) (Figure 10D): Cruz (1982), municipality of Itajibá, state of Bahia, Brazil.

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 Igaci; both from the state of Alagoas, Brazil; CHUFPB 28074–79 (n = 19, stage 37), municipality of Macaíba, 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.

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 Ibicuí, state of Bahia, Brazil.

Characteristics: Body rounded in dorsal view, triangular-obtuse 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 anterior, 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.

Specimens examined. *Lithobates palmipes*: MUFAL 10183, 1880–81 (n = 3, stage 36–40), municipality of Flexeiras, state of Alagoas, Brazil; CHUFPB 28537–40, CHUFPB 28546 (n = 20, stages 25–34), municipality of João Pessoa, state of Paraíba, Brazil; CHUFPB 28081 (n = 3, stage 37), municipality of Areia, state of Paraíba, Brazil; CHUFPB 22887 (n = 4, stages 33–35), municipality of Macaíba, state of Rio Grande do Norte, Brazil.

Characteristics: Body elliptical in dorsal view, slightly globular-depressed in lateral view. Snout oval in dorsal and lateral views. Nostrils circular, closer to tip of snout than to eyes. Eyes dorsal. Oral disc anteroventral, emarginate laterally. Marginal papillae arranged ventrolaterally, with a wide dorsal gap. LTRF 4(2,4)/4(1) or 3(2,3)/4(1). Spiracle sinistral. Vent tube dextral, attached to ventral fin. Dorsal fin originating at tail-body junction, dorsal and ventral fins arched. Tail length 60% of total length, tail tip acute.

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

- 1a. Oral disc lacking keratinized structures (jaws and/or labial teeth) ..... 2  
 1b. Oral disc with keratinized structures ..... 3  
 2a. (1a) One spiracle (Fig. 11a) ..... **MICROHYLIDAE** 11  
 2b. Two spiracles (Fig. 11b) ..... **PIPIDAE: *Pipa carvalhoi*** (Fig. 10e)  
 3a. (1b) Eyes positioned laterally (Fig. 11e) ..... 4  
 3b. Eyes positioned dorsally (Fig. 11f) ..... 5  
 4a. (3a) Spiracle ventral (Fig. 11c) ..... **PHYLLOMEDUSIDAE** 14  
 4b. Spiracle sinistral (Fig. 11d) ..... **HYLIDAE** 15  
 5a. (3b) Upper jaw sheath with a medial reentrance (Fig. 11n[i]) ..... **AROMOBATIDAE: *Allobates olfersioides*** (Fig. 3a)  
 5b. Upper jaw sheath arch-shaped (Fig. 11o[i]) or absent ..... 6  
 6a. (5b) Oral disc laterally emarginate (Fig. 11n[ii]) or modified in a single dermal fold on anterior lip (Fig. 11ab) ..... 7  
 6b. Oral disc not laterally emarginate or modified in two dermal fold 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 posterior lip with a single and broad medial interruption (Fig. 11v) or marginal papillae completely absent (Fig. 11ab) ...  
 ..... **BUFONIDAE** 54  
 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) ..... **ODONTOPHYRINIDAE** 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  
 11a. (2a) Anterior labial flaps extending beyond the posterior lip margin (Figs. 11r or 11s), dorsal fin originating at tail-body junction (Fig. 11i) ... 12  
 11b. Anterior labial flaps do not extend beyond the posterior lip margin (Fig. 11q), dorsal fin originating at body (Fig. 11h) .....  
 ..... ***Chiasmocleis alagoana*** (Fig. 9c)  
 12a. (11a) Labial flaps semicircular shaped (Fig. 11s) ..... ***Elachistocleis cesarii*** (Fig. 9e)  
 12b. Labial flaps square shaped (Fig. 11r) ..... 13  
 13a. (12b) Anterior portion of tail musculature thick with opaque fins (Fig. 9d), tail tip acute without flagellum .....  
 ..... ***Dermatonotus mulleri*** (Fig. 9d)  
 13b. Anterior portion of tail musculature thin without opaque fins (Fig. 9f), tail tip acute with flagellum .....  
 ..... ***Stereocyclops incrassatus*** (Fig. 9f)  
 14a. (4a) Posterior lip visible in dorsal view (Fig. 11g) ..... ***Hylomantis granulosa*** (Fig. 10c)  
 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 ..... 23  
 16a. (15a) Maximum ventral fin higher than tail musculature height, body triangular in lateral view (Fig. 2e) ..... ***Dendropsophus minutus*** (Fig. 5g)  
 16b. Maximum ventral fin height equal or less to tail musculature height, body triangular-depressed in lateral view (Fig. 2f) ..... 17



Identification key of Atlantic Forest's tadpoles

17a. (16b) Row of marginal papillae present (Fig. 11u[i])..... 18  
 17b. Row of marginal papillae absent (Fig. 11t)..... *Dendropsophus gr. microcephalus* 21  
 18a. (17a) Row of marginal papillae with two gaps on posterior lip (Fig. 11u[ii])..... 19  
 18b. Marginal papillae row without gaps on posterior lip..... *Dendropsophus gr. decipiens* 20  
 19a. (18a) Dorsal fin originating at body (Fig. 11h)..... *Dendropsophus soaresi* (Fig. 5c)  
 19b. Dorsal fin originating at tail-body junction (Fig. 11i)..... *Dendropsophus elegans* (Fig. 5b)  
 20a. (18b) Tail with homogeneous coloration or with small sparse spots near the fins edge, presence of a black bar at mid body (Fig. 4h).....  
 ..... *Dendropsophus haddadi* (Fig. 4h)  
 20b. Tail with large black cross-shaped bars or completely pigmented, black cross-shaped bars absent on body (Fig. 5a).....  
 ..... *Dendropsophus oliveirai* (Fig. 5a)  
 21a. (17b) Dorsal fin originating in the middle of the body (Fig. 11h), body length corresponding to 1/5 of total length .....  
 ..... *Dendropsophus branneri* (Fig. 5d)  
 21b. Dorsal fin originating at posterior body region or at tail-body junction (Fig. 11i), body length corresponding to 1/4 of total length .....  
 ..... 22  
 22a. (21b) Tail musculature width corresponding to half of body width, nostrils elliptical (Fig. 11af)..... *Dendropsophus nanus* (Fig. 5e)  
 22b. Tail musculature width corresponding to 60% of body width, nostrils rounded (Fig. 11ae) ..... *Dendropsophus studerae* (Fig. 5f)  
 23a. (15b) More than six labial teeth rows on oral disc ..... *Trachycephalus mesophaeus* (Fig. 7e)  
 23b. Less than six labial teeth rows on oral disc..... 24  
 24a. (23b) Presence of long marginal papillae interspersed by conical shorter ones (Fig. 11w), body ovoid in dorsal view (Fig. 2c), vent tube medial  
 (Fig. 11ah)..... *Sphaenorhynchus prasinus* (Fig. 7d)  
 24b. Marginal papillae with similar size and shape, body elliptical or elliptical-elongated in dorsal view (Figs. 2a or 2b), vent tube dextral (Fig. 11ag)  
 ..... *Scinax* 25  
 25a. (24b) Labial arm present (Fig. 11aa)..... 26  
 25b. Labial arm absent ..... 27  
 26a. (25a) Wide labial arm with more than 15 labial teeth..... *Scinax auratus* (Fig. 6e)  
 26b. Narrow labial arm with less than 10 labial teeth..... *Scinax nebulosus* (Fig. 6f)  
 27a. (25b) Maximum body height corresponding to half of body length, snout rounded or oval in lateral view ..... 28  
 27b. Maximum body height corresponding to 2/3 of body length, snout truncate or sloped in lateral view ..... 29  
 28a. (27a) Jaw sheaths narrow, submarginal papillae absent ..... *Scinax fuscomarginatus* (Fig. 7a)  
 28b. Jaw sheaths wide, submarginal papillae present (Fig. 11o[ii]) ..... *Scinax pachycrus* (Fig. 7b)  
 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. 11l) ..... 30  
 29b. Maximum body height in the region of vent tube insertion, ventral fin originating at midbody (Fig. 11m) ..... *Scinax x-signatus* (Fig. 7c)  
 30a. (29a) Spiracle aperture directed posterodorsally, nostrils elliptical (Fig. 11ae), located closer to eyes than to snout, submarginal papillae of  
 unequal size ..... *Scinax fuscovarius* (Fig. 6h)  
 30b. Spiracle aperture directed posteriorly, nostrils rounded (Fig. 11af), located closer to snout than to eyes, submarginal papillae of equal size  
 ..... *Scinax eurydice* (Fig. 6g)  
 31a. (10b) Dorsal fin originating on tail (Fig. 11j)..... *Aplastodiscus sibilatus* (Fig. 3g)  
 31b. Dorsal fin originating at body or tail-body junction (Figs. 11h or 11i)..... 32  
 32a. (31b) Ten or more labial teeth rows on oral disc ..... *Corythomantis greeningi* (Fig. 4g)  
 32b. Less than ten labial teeth rows on oral disc ..... 33  
 33a. (32b) Nostrils reniform (Figs. 11ac or 11ad)..... *Boana* 34  
 33b. Nostrils rounded or elliptic (Figs. 11ad or 11ae)..... 40  
 34a. (33a) Posterior lip with three labial teeth rows..... 35  
 34b. Posterior lip with four labial teeth rows ..... 36  
 35a. (34a) Body ovoid in dorsal view (Fig. 2c), presence of dark points distributed throughout the body, maximum dorsal fin twice higher than  
 ventral fin height, spiracle three times longer than wide with centripetal wall completely free ..... *Boana raniceps* (Fig. 3h)  
 35b. Body elliptical in dorsal view (Fig. 2a), absence of points on body, dorsal and ventral fins of the same height, spiracle wider than long with just  
 the final portion of the centripetal wall free ..... *Boana atlantica* (Fig. 4e)  
 36a. (34b) Body black or dark gray in ventral view (Fig. 4f), ventral fin arc shaped ..... *Boana semilineata* (Fig. 4f)  
 36b. Body cream or white in ventral view (Figs. 4a-4c), ventral fin parallel to caudal musculature ..... 37  
 37a. (36b) Body elliptical-elongated in dorsal view (Fig. 2b), oral disc ventral, dorsal fin originating in the last third of the body (Fig. 11h).....  
 ..... *Boana freicanecae* (Fig. 4d)  
 37b. Body ovoid or elliptical in dorsal view (Fig. 2a or 2c), oral disc anteroventral, dorsal fin originating at tail-body junction (Fig. 11i).....  
 ..... *Boana gr. faber* 38

- 38a. (37b) Absence of longitudinal strip pigmented in tail musculature and, in early stages, last third of tail dark brown (Fig. 4c) .....  
 .....**Boana faber** (Fig. 4c)
- 38b. Presence of longitudinal discontinued strip pigmented in the dorsal portion of the tail musculature (brown in life and cream in preservative), last third of tail with homogeneous coloration (Figs. 4a or 4b) .....39
- 39a. (38b) Fourth posterior row of labial teeth short, with length less than 3/4 of the length of third posterior row, absence of unpigmented circular spots on tail musculature.....**Boana albomarginata** (Fig. 4a)
- 39b. Fourth posterior row of labial teeth very short, with length less than 1/4 of the length of third posterior row, presence of unpigmented circular spots on tail musculature ..... **Boana crepitans** (Fig. 4b)
- 40a. (33b) Three posterior labial teeth rows, posterior lip concave when closed (Fig. 11z) .....**Ololygon** 41
- 40b. More than three posterior labial teeth rows, posterior lip not concave when closed ..... **Phyllodytes** 42
- 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) .....**Ololygon melanodactyla** (Fig. 5h)
- 42a. (40b). Oral disc ventrally modified in two cloven lobes on anterior lip, a small semicircular posterior lip, an abdominal sucker covering the first half of the body (Fig. 11k) ..... **Phyllodytes gyrinaethes** (Fig. 6d)
- 42b. Oral disc unmodified.....**Phyllodytes gr. luteolus** 43
- 43a. (42b) Body elliptical in dorsal view (Fig. 2a), dorsal fin originating in the last third of the body (Fig. 11h), five or more labial teeth rows on the posterior lip .....**Phyllodytes brevirostris** or **Phyllodytes edelmoi** (Fig. 6c)
- 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)
- 44a. (9b) Third posterior row of labial teeth short, with length less than half of the length of second posterior row .....45
- 44b. Posterior labial teeth rows equal in length.....46
- 45a. (44a) Marginal papillae row with three gaps on the posterior lip (Fig. 11x) .....  
 ..... **Physalaemus albifrons** (Fig. 8f) or **Physalaemus cuvieri** (Fig. 8g)
- 45b. Marginal papillae row without gaps on the posterior lip.....**Pleurodema diplolister** (Fig. 8h)
- 46a. (44b) Marginal papillae row with two gaps on the posterior lip (Fig. 11y).....**Pseudopaludicola** 47
- 46b. Marginal papillae row without gaps on the posterior lip.....**Physalaemus caete**
- 47a. (46a) Presence of dark spots on fins (Fig. 9a), body elliptical in dorsal view (Fig. 2a) ..... **Pseudopaludicola mystacalis** (Fig. 9a)
- 47b. Absence of dark spots on fins (Fig. 9b), body ovoid in dorsal view (Fig. 2c) .....**Pseudopaludicola pocoto** (Fig. 9b)
- 48a. (10a) Three labial teeth rows on oral disc ..... **Leptodactylus vastus** (Fig. 8e)
- 48b. Five labial teeth rows on oral disc ..... 49
- 49a. (48b) Second anterior labial teeth row with medial gap, a simple row of marginal papillae in the posterior lip.....**Leptodactylus gr. fuscus** 50
- 49b. Second anterior labial teeth row without medial gap, two or three rows of marginal papillae in the posterior lip .....53
- 50a. (49a) Dorsal portion of tail musculature fully pigmented (brown in life and cream in preservative, Fig. 7g), lower jaw sheath U-shaped (Fig. 11o[iii]) .....**Leptodactylus caatingae** (Fig. 7g)
- 50b. Tail musculature with unpigmented homogeneous coloring or with sparse dark stains (Figs. 7h-8b), lower jaw sheath V-shaped (Fig. 11n[iii]) .....51
- 51a. (50b) Maximum body width on the half or on the last third of the body, second anterior labial teeth short, with a medial gap corresponding to about 13 labial teeth and, from stage 36, presence of three or more dark brown transverse bars on dorsum .....  
 .....**Leptodactylus troglodytes** (Fig. 8b)
- 51b. Maximum body width just behind the eyes, second anterior labial teeth with a medial gap corresponding to about 30 labial teeth, without pigmentation on body .....52
- 52a. (51b) Interorbital distance less than 40% of body width, spiracle twice longer than wide with centripetal wall completely fused to wall of the body .....  
 ..... **Leptodactylus mystaceus** (Fig. 8a)
- 52b. Interorbital distance greater than 40% of body width, spiracle about the same width and length with the final portion of the centripetal wall free. ....**Leptodactylus fuscus** (Fig. 7h)
- 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)
- 53b. Oral disc without ventral folds, eye diameter with half the distance from nostrils to the snout .....**Leptodactylus macrosternum** (Fig. 8c)
- 54a. (8a) Presence of marginal papillae .....**Rhinella** 55
- 54b. Marginal papillae completely absent (Fig. 11ab).....**Frostius pernambucensis** (Fig. 3b)
- 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
- 56a. (55b) Body with light coloration in dorsal view, ranging from cream to dark cream (Fig. 3e), weakly pigmented tail musculature, with homogeneous color (Fig. 3e).....**Rhinella hoogmoedi** (Fig. 3e)

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- 56b. Body with dark coloration in dorsal view, ranging from dark brown to black (Figs. 3c or 3f), tail musculature strongly pigmented, longitudinal strip unpigmented in the ventral portion of the tail musculature (Figs. 3c or 3f).....57
- 57a. (56b) Body elliptical in dorsal view (Fig. 2a), eye diameter equal or larger than the distance from nostrils to the snout, first third of dorsal fin with concave contour ..... *Rhinella crucifer* (Fig. 3c)
- 57b. Body ovoid in dorsal view (Fig. 2c), eye diameter with half the distance from nostrils to the snout, first third of dorsal fin with arched contour ..... *Rhinella jimi* (Fig. 3f)
- 58a. (9a) Body rounded in lateral view (Fig. 2d), anterior margin of oral disc totally fused with body wall, tail short, representing approximately 50% of total length ..... *Macrogenioglottus alipioi* (Fig. 9g)
- 58b. Body globular/depressed in lateral view (Fig. 2i), anterior margin of oral disc free, tail representing more than 60% of total length ..... 59
- 59a. (58b) Second anterior labial teeth row with medial gap, body ovoid in dorsal view (Fig. 2c) ..... *Proceratophrys* 60
- 59b. Second anterior labial teeth row without medial gap, body elliptical in dorsal view (Fig. 2a) ..... *Odontophrynus carvalhoi* (Fig. 9h)
- 60a. (59a) Body dark brown in dorsal view (Fig. 10b), nostrils reniform (Figs. 11ac or 11ad), centripetal wall of spiracle free from body ..... *Proceratophrys renalis* (Fig. 10b)
- 60b. Body light brown in dorsal view (Fig. 10a), nostrils rounded (Fig. 11ae), centripetal wall of spiracle fused to body ..... *Proceratophrys cristiceps* (Fig. 10a)

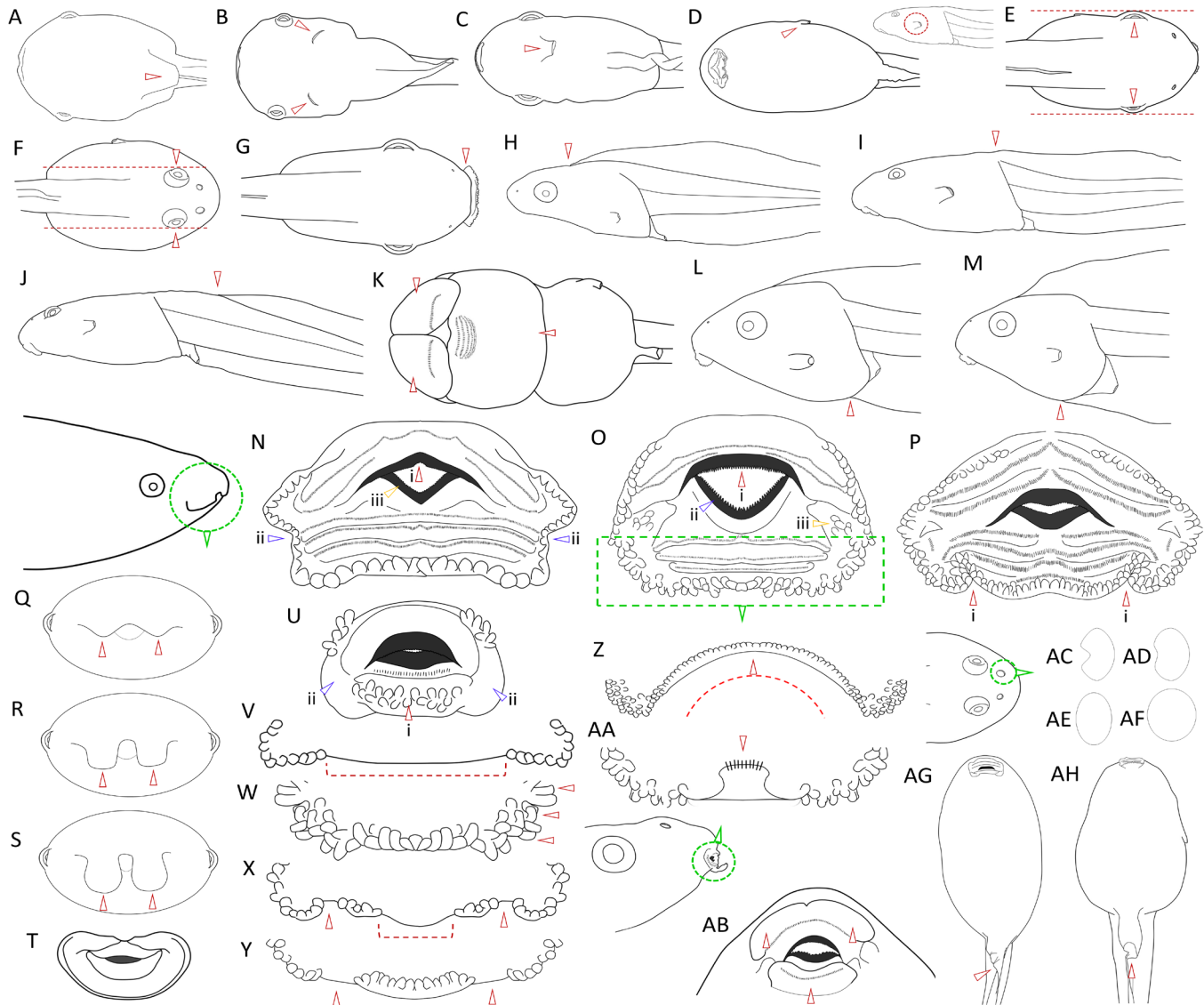


Figure 11. Morphological characteristics used to larval characterizations and in the taxonomic key. Details of characteristics are mentioned in the taxonomic key.

## 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 suctorials, raspers, carnivorous, macrophages and endotrophics (Dubeux et al. 2019). Most tadpoles develop in lentic or lotic environments, but five in phytotelmata (*Frostius pernambucensis* and *Phyllodytes* spp.), one in association with rocky streams (*Corythomantis greeningi*) and one probably has endotrophic tadpoles that complete development in a foam nest placed in an underground burrow (*Adenomera* aff. *hylaedactyla*). Unfortunately, the feeding habit and microhabitat use for several tadpoles remain unknown (Dubeux et al. 2019).

Tadpole identification remains an enormous challenge in the Neotropics mostly due to the difficulty in recognizing and distinguishing morphological characteristics. Dichotomous keys are important tools for identifying organisms. Although the first identification keys for tadpoles were published more than a century ago (Boulenger 1892, Altig 1970, Lips & Savage 1996, Mijares-Urrutia 1998), they included few characteristics and few illustrations without enough details. Currently, a dozen or so identification keys are available for tadpoles, most of them for small groups of species (Haas et al. 2009, see below) or restricted regions (e.g., Hero 1990, Rossa-Feres & Nomura 2006).

The first tadpole key for Brazilian species was developed by Hero (1990) and included 36 species that occur in the municipality of Manaus, state of Amazonas. Despite this beginning, most taxonomic keys available for tadpoles in Brazil are concentrated in the South and Southeastern regions. Rossa-Feres & Nomura (2006) included 22 species in a key for tadpoles of northwest region of São Paulo state. A year later, Machado & Maltchink (2007) published a key included 44 taxa (species and genera) of the state of Rio Grande do Sul. A tadpole key published in a book included 49 species obtained in the municipalities of Conceição do Mato Dentro, Alvorada de Minas and Dom Joaquim, all in state of Minas Gerais (Pimenta et al. 2014). Four years later, an identification key for 11 species from Ilha Grande, state of Rio de Janeiro, was published (Fatorelli et al. 2017). Recently, an interactive identification key was made available online, including 66 species from a region designated *Quadrilátero Ferrífero*, in the state of Minas Gerais (Pezzuti et al. 2019). Herein, we provide an key for tadpoles in the northern region of the Atlantic Forest, the first for Northeastern Brazil, contributing to fill one of the knowledge gaps identified during the “Tadpoles International Workshop” (Rossa-Feres et al. 2015): “How can we improved taxonomic identification of larval stages?”. We expect this key and the morphological characterization of tadpoles presented here will stimulate further studies with Brazilian larval anurans.

## 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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## Conflicts of Interest

The author(s) declare(s) that they have no conflict of interest related to the publication of this manuscript.

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