SHORT COMMUNICATION

Defensive repertoire of *Leptodactylus rhodomystax* (Anura: Leptodactylidae) in the Brazilian Amazon

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Anuran amphibians are common prey for a wide variety of vertebrate and invertebrate predators (Duellman and Trueb 1994, Toledo *et al.* 2007). In response to the selective pressures exerted by these predators, this group has developed a series of antipredator defense mechanisms that may include ecological, morphological, physiological, and/or behavioral aspects (Toledo *et al.* 2011, Ferreira *et al.* 2019). These strategies can be divided into three main phases: avoiding detection by predators (e.g., camouflage), preventing attack (e.g., aposematism), and reacting during attack (e.g., use of skin secretions) (Ferreira *et al.* 2019). These strategies can be employed independently in the presence of a potential predator (e.g., venom, aposematism, camouflage) or used in the presence of and/or direct interaction with the predator (e.g., fleeing, feigning death, biting) (Edmunds 1974, Toledo *et al.* 2011).

The genus *Leptodactylus* Fitzinger, 1826 is one of the most diverse groups of anurans, widely distributed across the Neotropical region (de Sá *et al.* 2014, Frost 2024). It is comprised of medium- to large-sized species that exhibit diverse ecology, occupying various environmental niches (Heyer 1979, de Sá *et al.* 2014). *Leptodactylus rhodomystax* Boulenger, 1884, belonging to the *L. pentadactylus* group, is characterized by its medium size (maximum SVL of 91.4 mm in females and 89.6 mm in males), the presence of a light stripe on the upper lip, and distinct light spots (usually yellow or white) on the posterior surface of the thigh against a dark background (Heyer 1979). This species has terrestrial and nocturnal habits, typically occupying forest environments (Barrio-Amorós *et al.* 2019, Gagliardi-Urrutia *et al.* 2022). It has a wide distribution, found in the Amazonian regions of the Guianas (including Suriname and Venezuela), extending through Brazil, Colombia, Ecuador, and Peru (Frost 2024). The defensive repertoire of this species is poorly known, with records limited to death-

feigning (Ramalho *et al.* 2019) and stretching limbs (Pedroso-Santos *et al.* 2022). Here, we present a compilation of the defensive strategies used by *L. rhodomystax,* including documentation of new behaviors employed by the species.

Data were obtained during field expeditions conducted in 2009 and 2013 in the municipalities of Canutama (06°32'02" S, 64°22'58" W, WGS 84; Figure 1B) in the state of Amazonas, Brazil, and in the municipalities of Cotriguaçu (09°51'28" S, 58°24'50" W, WGS 84; Figure 1E) and Paranaíta (09°39'54" S, 56°28'37" W, WGS 84; Figure 1A, C–D, F), both located in the state of Mato Grosso, Brazil. All strategies displayed by individuals were performed in non-natural environments during *ex situ* photographic sessions of the specimens. We photographed all defensive behaviors exhibited and classified the strategies according to the terminology proposed by Ferreira *et al.* (2019).

We recorded five types of defensive strategies performed by four individuals of *L. rhodomystax:* (1) hidden aposematism, (2) rear elevation, (3) body inflation, (4) body elevation (full and partial), and (5) skin secretion. Exhibitions of body inflation and rear elevation, along with display of the internal patterns of the thighs (hidden aposematism), were performed synergistically by Individual 1 (Figure 1B); full body elevation was exhibited simultaneously with body inflation by Individual 2 (Figure 1C, D); partial body elevation was performed by Individual 3 (Figure 1E); and skin secretions were recorded in Individual 4 (Figure 1F). The observed behaviors can be utilized in phases of attack prevention (hidden aposematism, rear elevation, body inflation, and body elevation) and counter-attack (skin secretion).

The behavior of rear elevation, also known as body-raising (Toledo *et al.* 2011), involves raising the posterior part of the body by fully or partially extending the hind legs (Ferreira *et al.* 2019). During this display, *L. rhodomystax* exhibits aposematic patterns characterized by spots, usually vibrant yellow, on the posterior region of the thighs that strongly contrast with the black background (Figure 1A). These spots are also visible during displays of stretching limbs, a strategy that can be classified as a type of hidden aposematism (Ferreira *et al.* 2019, Pedroso-Santos *et al.* 2022).

The strategy of body inflation occurred synergistically with displays of rear elevation and full body elevation. In this behavior, the individual inflates its lungs with air, thereby increasing its size (Toledo *et al.* 2011, Ferreira *et al.* 2019). During full body elevation, the individual extends both its front and hind limbs completely to appear larger and more intimidating to potential predators (Figure 1D). In contrast, during partial body elevation, the individual extends only its front limbs, spreading them slightly apart and adopting a more upright posture. This position not only increases the individual's size but may also expose the spines located on the phalanges and chest region of sexually active males, potentially facilitating spine aggression (Toledo *et al.* 2005, Oliveira-Santos *et al.* 2023). Additional presumed functions of these mechanisms include making it more difficult for predators to ingest an individual and making it harder for predators to grasp an individual (Ferreira *et al.* 2019).

Many amphibians use skin secretions as anti-predatory defense mechanisms (Ferreira *et al.* 2019). These secretions can have odoriferous, adhesive, slippery, and/or toxic properties (Brizzi and Corti 2007, Toledo *et al.* 2005). When handled, *L. rhodomystax* can produce a foamy substance with a viscous and slippery appearance, concentrated mainly in the inguinal region (Figure 1F). Although biochemical tests to confirm the compounds in the secretion could not be conducted, we believe that it has slippery and/or toxic effects like species in the *L. pentadactylus* group, commonly known as Pepper Frogs, that produce substances rich in peptides with toxic effects (Toledo *et al.* 2005, Carrillo *et al.* 2024).

Although the strategies described here are the first records for *L. rhodomystax* (except for hidden aposematism; see Pedroso-Santos *et al.* 2022), there are reports of similar behaviors in other species within the genus, especially in the

Figure 1. Defensive strategies used by *Leptodactylus rhodomystax* in the Brazilian Amazon. (**A**) Posterior thigh region displaying hidden aposematic patterns; (**B**) rear elevation; (**C–D**) full body elevation with body inflation; (**E**) partial body elevation; (**F**) exudation of skin secretion. Photos: RWA (A, C, D, F), VTC (B), RAK-R (E).

L. pentadactylus group. These include displays of posture mechanisms (body elevation, body inflation, and/or rear elevation) in *L. knudseni* Heyer, 1972, *L. labyrinthicus* (Spix, 1824), *L. pentadactylus* (Laurenti, 1768), *L. rhodonotus* (Günther, 1869), *L. stenodema* Jiménez de la Espada, 1875, and *L. vastus* Lutz, 1930; skin secretion in *L. flavopictus* Lutz, 1926, *L. knudseni, L. labyrinthicus, L. pentadactylus, L. savagei* Heyer, 2005, and *L. vastus;* and hidden aposematic patterns in *L. knudseni, L. labyrinthicus, L. pentadactylus, L. rhodonotus,* and *L. vastus* (Toledo *et al.* 2005, 2011, Castro *et al.* 2017, Ferreira *et al.* 2019).

Even while remaining motionless, anurans can employ a variety of strategic mechanisms to deter predator attacks (Toledo *et al.* 2011). Postural mechanisms, such as rear elevation, are frequently accompanied by the simultaneous display of hidden aposematic coloration, skin secretion production, and body inflation (Castro *et al.* 2017, Ferreira *et al.* 2019). Our observations of *L. rhodomystax,* along with reports from other species within the *L. pentadactylus* group, suggest that species in this group may synergistically utilize this sequence of behaviors to enhance their survival against predator attacks. These findings contribute to our understanding of the defensive strategies employed by these species and the behavioral patterns adopted by phylogenetically related species.

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