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Defensive behavior of *Adelophryne nordestina* (Anura: Eleutherodactylidae) in an Atlantic Forest fragment in Northeast Brazil

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Resumo

A predação é uma das pressões seletivas mais significativas que afetam a sobrevivência na natureza, levando as espécies a desenvolverem estratégias de defesa decisivas. Os anuros exibem um repertório diverso de comportamentos defensivos voltados à proteção dos indivíduos em diferentes estágios da predação, mas a função desses comportamentos varia entre as espécies. Este estudo documenta comportamentos defensivos observados na rã miniaturizada *Adelophryne nordestina*. Observamos comportamentos de mouth gaping e de death feigning (tanatose) em uma pequena parcela dos indivíduos amostrados, sem correlação entre o tamanho corporal e a presença dos comportamentos defensivos. Comportamentos semelhantes foram observados de forma pontual em outras espécies do mesmo gênero e entre outros anuros miniaturizados. Dada a baixa prevalência desses comportamentos nesta espécie, estratégias defensivas alternativas, como a coloração críptica, podem desempenhar um papel mais decisivo na sobrevivência da espécie. Informações sobre os predadores de *A. nordestina* são necessárias para esclarecer o papel de cada estratégia na interação predador-presa.

Palavras-chave: Coloração críptica, Estratégia de defesa, Predação, Rãs miniaturizadas, Tanatose.

Abstract

Predation is one of the most significant selective pressures affecting survival in nature, compelling species to develop crucial defense strategies. Anurans exhibit a diverse repertoire of defensive behaviors aimed at safeguarding individuals across various stages of predation, but the roles of these behaviors differ among species. This study documents defensive behaviors observed in the miniaturized frog *Adelophryne nordestina*. We observed mouth gaping and death feigning behaviors in a small subset of the sampled individuals, without correlation between individual size and the defensive behaviors. Similar behaviors have been serendipitously observed in other species within the genus and among other miniaturized anurans. Given their low prevalence in this species, alternative defensive strategies such as cryptic coloration may play a more decisive role in species survival. Information about predators of *A. nordestina* is needed to clarify the role of each strategy on their predator-prey interaction.

Key words: Death Feigning, Miniaturized frogs, Mouth Gaping, Predation, Thanatosis.

INTRODUCTION

Predation is one of the major selective pressures acting on species and the use of efficient defense strategies against predators is indispensable for species survival. Anurans are recognized for having a wide range of defensive characteristics including morphological, physiological, or behavioral that may be expressed permanently or only in the presence of a potential predator (Duellman & Trueb, 1994; Toledo et al., 2011; Ferreira et al., 2019). Various defense mechanisms are often expressed simultaneously by the same individual, increasing the chances of success. Some species of the genus *Proceratophrys* Miranda-Ribeiro, 1920, for example, have been observed combining their typical cryptic coloration with behavioral defenses, such as inflating the body or stiffening legs, distress call (Mângia & Garda, 2015) and the discharge of secretions (Meneses & Correa, 2020).

Mouth-gaping, according to Toledo et al. (2011), is a defensive behavior that involves the opening of the mouth in the presence of a predator, either once or repeatedly, with the intention of avoiding subjugation through predator intimidation. This defensive behavior can be combined with other behaviors, such as distress calls and bites, or revealing contrasting colors of the tongue or mouth in some species (Duellman & Trueb, 1994; Toledo et al., 2011; Ferreira et al., 2019). Mouth-gaping in miniature species may serve as a mechanism to confuse invertebrate predators. In contrast, death feigning, or thanatosis, is the behavior of assuming a motionless posture resembling that of a dead animal. Some species may exhibit aposematic coloration on the ventral surface or limbs (Ferreira et al., 2019). This behavior allows the frog to avoid predation by deceiving predators, especially those reliant on movement to detect prey, and the prey avoids injury from predators. It is one of the most frequently reported defensive behaviors in anurans (Toledo et al., 2010; Ferreira et al., 2019).

The genus *Adelophryne* Hoogmoed and Lescure, 1984, is currently composed of 12 species of miniaturized and cryptic frogs with a maximum snout–vent length (SVL) of 23 mm, inhabiting the leaf litter in the Brazilian Atlantic Forest, Amazon, and the Guiana Shield (Fouquet et al., 2012; Frost, 2025). Until now, ecological studies of the genus were restricted to *Adelophryne maranguapensis* Hoogmoed et al., 1994 and *A. baturitensis* Hoogmoed et al., 1994 (Cassiano-Lima et al., 2011; Cassiano-Lima et al., 2020; Oliveira et al., 2022; Araújo et al., 2023). Information on the ecology and behavior of other *Adelophryne* species is limited to their species descriptions or serendipitous observations.

Adelophryne nordestina Lourenço-de-Moraes et al. 2021 is found in the Atlantic Forest of Northeast Brazil with three known populations with disjunct distribution in Paraíba, Pernambuco, and Alagoas States (Lourenço-de-Moraes et al., 2021). In this study, we report our observations on the defensive behavior of *A. nordestina*, in a "Brejo de Altitude", a remnant of Atlantic Forest inserted on the semiarid environment of Caatinga ecoregion, of Northeastern Brazil.

MATERIAL AND METHODS

The study was conducted in Parque Nacional Municipal Professor João Vasconcelos Sobrinho, a conservation unit on the Serra dos Cavalos mountain range (-8.373º, -36.026º), in Pernambuco, Brazil. We observed frog populations for 42 days from November 2021 to September 2022. Males were calling during every month of the study period, from early morning until nightfall. As part of a broader study, we collected a few individuals each month, measured them using digital calipers (accuracy of 0.01 mm), and determined their sex through direct observation of the gonads. The specimens were deposited in the Herpetological Collection of the Federal University of Ceará (CHUFC). To assess whether there is a relationship between the displayed defensive behavior and the size of the individuals, we performed a Welch's test using Jamovi 2.3 (The Jamovi Project, 2022).



Figure 1. A, B) Male *Adelophryne nordestina* exhibiting mouth-gaping behavior (UFC-A11226 and UFC-A11220, respectively). **C**) The female *A. nordestina* also exhibits mouth-gaping behavior (UFC-A11253). The specimens were photographed in a terrarium simulating their natural environment. Photos by Laiana Carla de Moura.

RESULTS

We recorded two defensive behaviors while the frogs were handled during photographing or weighing. Mouth-gaping was observed in eight individuals ($n = 4$, males; $n = 3$, females; $n = 1$, undetermined; Fig. 1) from a total of 86 adults ($n = 31$ males; $n = 50$, females; $n = 5$, undetermined). The mean SVL of individuals exhibiting mouth-gaping was 12.41±0.90 mm (range 11.45 to 13.51 mm). Mouth-gaping behavior was not correlated with body size (Welch's t = 0.08). Death feigning behavior was observed in four males and one female. These frogs have a mean SVL of 11.84 ± 1.20 mm (range 10.39 to 13.55 mm). No significant difference was found in SVL between individuals displaying this defensive behavior and those that did not exhibit it (Welch's t = 0.97).

DISCUSSION

The mouth-gaping behavior has been reported in various unrelated anuran species. Recent comprehensive studies on defensive behaviors of anurans documented the occurrence of mouth-gaping in 66 species belonging to at least 16 families (Toledo et al., 2011, and Ferreira et al., 2019). Among miniaturized species, mouth-gaping is frequently observed in members of the genus *Brachycephalus* Fitzinger, 1826 (Toledo et al., 2011; Goutte et al., 2017; Ferreira et al., 2019; Nunes et al., 2021), that also inhabit the leaf litter of the Brazilian Atlantic Forest, a habitat similar to that of *Adelophryne nordestina*. Among *Adelophryne,* mouth-gaping has been occasionally reported for species such as *A. glandulata* Lourenço de Moraes, Ferreira, Fouquet, and Bastos, 2014 (Lourenço-de-Moraes et al., 2014), which also exhibits fleeing, immobility, and body inflating behaviors, and *A. mucronata* Lourenço-de-Moraes, Solé, and Toledo, 2012 (Lourenço-de-Moraes et al., 2012). Despite being relatively well-studied in terms of reproduction (Cassiano-Lima et al., 2011; Cassiano-Lima *et al*., 2020), parasitism (Oliveira et al., 2022) and feeding ecology (Araújo et al., 2023), defensive behavior in *A. baturitensis* and *A. maranguapensis* has not been reported.

Similar to *A. nordestina*, no other *Adelophryne* species has been observed to exhibit biting behaviors or distress calls associated with mouth-gaping. Although distress calls (*sensu stricto* Toledo et al., 2014) are commonly emitted alongside mouth-gaping, they are produced only by medium to large-sized species and might be inefficient for smaller species (Toledo and Haddad, 2009; Forti et al., 2018). Similarly, biting behaviors are typical of larger species with wide mouths, whose jaws have stronger musculature and bony apparatus, resulting in a greater bite force (Duellman & Trueb, 1994; Toledo et al., 2011; Ferreira et al., 2019).

Although death feigning is the most common defense mechanism displayed by frogs, there are, to our knowledge, no studies on the prevalence of this behavior in anurans that exhibit other types of defensive behavior.

Nevertheless, the low prevalence of these defensive behaviors in *A. nordestina* may indicate that other defense mechanisms to avoid the detection and identification by the predator, such as cryptic coloration, can be more effective for the species' survival (Toledo & Haddad, 2009). Future natural history studies on this species should include investigating their predators to elucidate the effectiveness of this defense mechanism for *A. nordestina*.

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