

Defensive behaviors in two *Proceratophrys* species (Anura: Odontophrynidae) from central Brazilian Cerrado

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ABSTRACT

Anurans present a wide array of defensive displays, which are exhibited in different phases of predation. There are several records of defensive behaviors for the genus *Proceratophrys*, most of them in species from the Atlantic Forest. Besides, few is known about such displays in Cerrado species. Herein, we report new defensive behaviors for *P. goyana* and *P. vielliardi*, of the *P. cristiceps* group. Both species presented immobility, body inflation and production of secretions. The stiff-legged behavior was commonly reported for the Atlantic Forest species of *Proceratophrys*, along with contraction. To date, body inflation, digging, and distress calls were only recorded in the *P. cristiceps* group. Our observations on defensive behaviors, account for the still poorly know natural history of the genus *Proceratophrys*.

Key Words: Brazil; Neotropical region; *Proceratophrys goyana*; *Proceratophrys vielliardi*; South America.

Anurans can display various defensive strategies (Toledo *et al.*, 2011), including a wide range of features, such as morphological, behavioral, and physiological traits to avoid predation (Duellman and Trueb, 1994). About 12 antipredator mechanisms were quoted for anurans, with 28 variations (Ferreira *et al.*, 2019). These features are displayed in different phases of predation (Edmunds, 1974; Ferreira *et al.*, 2019), and defensive behaviors are related to predator's strategies for locating and subjugating anuran prey (Greenbaum, 2004).

The genus *Proceratophrys* Miranda-Ribeiro, 1920 is composed of 41 species distributed across eastern and southern Brazil, with records also in Argentina and Paraguay (Frost, 2020). Of those species, 11 have been registered in the Brazilian Cerrado ecoregion, from where eight of them are considered endemisms: *P. bagnoi*, *P. branti*, *P. cururu*, *P. dibernardo*, *P. moratoi*, *P. strussmannae*, *P. rotundipalpebra*, and *P. vielliardi* (Valdujo *et al.*, 2012; Brandão *et al.*, 2013; Martins and Giaretta, 2013).

In the Distrito Federal region, within central

Brazilian Cerrado two species were recorded, *P. goyana*, and *P. vielliardi* (Brandão *et al.*, 2012; Brandão and Araújo, 2001), both of them belonging to the *P. cristiceps* group (Giaretta *et al.*, 2000). *Proceratophrys goyana* (Miranda-Ribeiro, 1937) has a wide distribution in the central portion of Brazil (Teixeira Jr *et al.*, 2012; Martins and Giaretta 2013). It is associated with lotic waters both in forested and open physiognomies (Santoro and Brandão, 2014; Carvalho *et al.*, 2020). *Proceratophrys vielliardi* Martins and Giaretta, 2011 has a narrow distribution in the central portion of the Cerrado (Martins and Giaretta, 2011; Brandão *et al.*, 2012). This species is associated with seasonal rocky brooks and streams at high altitudes in open physiognomies (Martins and Giaretta, 2011; Brandão *et al.*, 2012), such as "campo limpo" and "campo sujo" (*sensu* Ribeiro and Walter, 2008).

Various defensive behaviors have been already reported for *Proceratophrys*, most of them correspond to species of the Atlantic Rain Forest ecoregion (Sazima, 1978; Weygoldt, 1986; Toledo and Zina, 2004; Costa *et al.*, 2009; Moura *et al.*, 2010; Toledo

et al., 2011; Lourenço-de-Moraes and Lourenço-de-Moraes, 2012; Peixoto *et al.*, 2013; Mângia and Garda, 2015; Ferreira *et al.*, 2019; Table 1). Herein, we report the first records of defensive behaviors for two Cerrado species, *P. goyana*, and *P. vielliardi*.

The individuals were found at Fazenda Água Limpa (15°58'31.5"S, 47°56'56.1"W, 1175 m a.s.l.), and at APA do Cafuringa (15°33'13.6"S, 47°51'59.8"W, 769 m a.s.l.), Brasília, Distrito Federal, Brazil. None of the individuals were collected. On 16 August 2018, at 19:01 h, at APA do Cafuringa we found a male of *P. goyana* vocalizing in the leaf litter at the margins of a stream. When first spotted, it displayed crouching down behavior and remained immobile (Fig. 1A). When startled by our close presence, it jumped, inflated the body, and remained in this posture for some seconds, while also discharging secretions (Fig. 1B). Afterwards, it attempted to flee from us with small jumps into the leaf litter.

On 25 October 2018, at 21:03 h, at Fazenda Água Limpa we found an individual of *P. vielliardi* vocalizing at the margins of a creek. When spotted, it stopped vocalizing and remained immobile. While manipulated, the specimen inflated the body, mostly the abdomen (puffing up behavior), and remained motionless for some seconds (Fig. 2A). After this, and once put on the floor, the frog attempted to flee back to the creek with fast and erratic jumps. We also

found a second individual of the same species on 03 November 2018, at 22:23 h, at the same locality, vocalizing at the margins of a creek. It also presented immobility when first spotted, followed by puffing up the body (again, mostly the abdomen) when startled, and remained motionless for a few seconds while the body was inflated. After that, it elevated the posterior part of the body, while lowering its head and discharging secretions (Fig. 2B).

Immobility and fleeing are the most common defensive behaviors amongst anurans (Toledo *et al.*, 2011). These behaviors combined with the cryptic coloration of the genus *Proceratophrys* (Toledo and Haddad, 2009), can be very effective in avoiding predation by visually-oriented predators (Marchisin and Anderson, 1978; Cooper *et al.*, 2008). Along with immobility, crouching down may also aid in escaping from this kind of predators (Marchisin and Anderson, 1978; Toledo *et al.*, 2011). Puffing up the body consists of filling the lungs with air (Toledo *et al.*, 2011), to prevent subjugation by a potential predator (Toledo *et al.*, 2011; Ferreira *et al.*, 2019). Besides, it may also be displayed before a subjugation attempt, even in the ground, water, or vegetation (Toledo *et al.*, 2011; Mângia and Garda, 2015), like was observed in the individuals we studied. Discharging noxious secretions is also another common defensive behavior in anurans when threatened,



Figure 1. Defensive displays of *Proceratophrys goyana*, crouching down (A) and puffing up the body, while discharging skin secretions (B) (Photos by ASOM).



Figure 2. Defensive displays of *Proceratophrys vielliardi*, puffing up the body (A) and puffing up while discharging secretions (B) (Photos by ASOM).

and would avoid subjugation (Toledo *et al.*, 2011; Ferreira *et al.*, 2019). Production of secretions may happen synergistically with other behaviors, such as immobility, crouching down, and puffing up the body (Toledo *et al.*, 2011).

Stretching limbs was commonly reported as a defensive behavior for the Atlantic Rain Forest species of *Proceratophrys* (Weygoldt, 1896; Sazima,

1978; Toledo and Zina, 2004; Costa *et al.*, 2009; Moura *et al.*, 2010; Toledo *et al.*, 2011; Peixoto *et al.*, 2013; Ferreira *et al.*, 2019). There are no records of the stiff-legged behavior in the *P. cristiceps* group, and other behaviors displayed by *Proceratophrys* (e.g. body inflation, digging, and distress calls) were to date only documented in this group (Toledo *et al.*, 2011; Mângia and Garda, 2015; this work; Table

Table 1. Defensive displays recorded in the genus *Proceratophrys*.

Species	Defensive displays	Association	Reference
<i>Proceratophrys appendiculata</i>	Stretching limbs	Atlantic Rain Forest	Sazima, 1978
<i>Proceratophrys avelinoi</i>	Contraction	Atlantic Rain Forest	Lourenço-de-Moraes and Lourenço-de-Moraes, 2012
<i>Proceratophrys boiei</i>	Stretching limbs	Atlantic Rain Forest	Toledo and Zina, 2004; Costa <i>et al.</i> , 2009
<i>Proceratophrys cristiceps</i>	Puffing up the body, mouth gaping, distress calls, fleeing	Caatinga	Mângia and Garda, 2015
<i>Proceratophrys cururu</i>	Digging	Cerrado	Toledo <i>et al.</i> , 2011
<i>Proceratophrys goyana</i>	Puffing up the body, crouching down, discharge of secretions, fleeing	Cerrado/Caatinga	This work
<i>Proceratophrys melanopogon</i>	Stretching limbs	Atlantic Rain Forest	Moura <i>et al.</i> , 2010
<i>Proceratophrys moehringi</i>	Stretching limbs	Atlantic Rain Forest	Weygoldt, 1896
<i>Proceratophrys moratoi</i>	Digging	Cerrado	Toledo <i>et al.</i> , 2011
<i>Proceratophrys paviotti</i>	Gland exposure posture	Atlantic Rain Forest	Ferreira <i>et al.</i> , 2019
<i>Proceratophrys renalis</i>	Stretching limbs	Atlantic Rain Forest	Peixoto <i>et al.</i> , 2013
<i>Proceratophrys schirchi</i>	Stretching limbs	Atlantic Rain Forest	Ferreira <i>et al.</i> , 2019
<i>Proceratophrys vielliardi</i>	Puffing up the body, discharge of secretions, fleeing	Cerrado	This work

1). Except for *P. concavitympanum*, which presents distribution in transitional areas between Cerrado and Amazon Rain Forest (Ávila *et al.*, 2012; Teixeira Jr *et al.*, 2012), all the species of this group are associated with seasonally dry open physiognomies in Cerrado and Caatinga biomes (Brandão *et al.*, 2013; Giaretta *et al.*, 2000; Teixeira Jr *et al.*, 2012). Since stretching limbs is a defensive behavior commonly presented in leaf litter anurans (Mângia and Santana, 2013), the absence of records of this display in the *P. cristiceps* group is possibly due to its association with open phytophysiognomies (Loebmann and Haddad, 2010; Brandão *et al.*, 2012; Santoro and Brandão, 2014), where the leaf litter is scarce (Ribeiro and Walter, 2008). However, the stiff-legged behavior has already been recorded in a species that inhabit open physiognomies (e.g. *Pleurodema bibroni*, Kolenc *et al.*, 2009, as death feigning), perhaps due to evolutionary constraints. Although not yet recorded, it is possible that the *P. cristiceps* species group also presents the stiff-legged behavior.

Members of Odontophrynidae, other than *Proceratophrys*, present similar defensive behaviors. Puffing up the body, crouching down and production of secretions have been recorded in several species of *Odontophrynus* (Borteiro *et al.*, 2018), but stretching limbs was only seen in *O. americanus* (Maffei and Ubaid, 2016; Borteiro *et al.*, 2018). There are other records of the stiff-legged behavior within Odontophrynidae in species inhabiting the leaf litter, *Proceratophrys* spp. (Weygoldt, 1896; Sazima, 1978; Toledo and Zina, 2004; Costa *et al.*, 2009; Moura *et al.*, 2010; Toledo *et al.*, 2011; Peixoto *et al.*, 2013; Ferreira *et al.*, 2019), and *Macrogenioglottus alipioi*, a species that also presents body inflation and tilting (Mira-Mendes *et al.*, 2016).

The natural history of species of the genus *Proceratophrys*, for instance regarding defensive and reproductive behaviors, is poorly known (Mângia and Garda, 2015; Carvalho *et al.*, 2020). The increasing knowledge of its defensive displays would allow to study the evolution of these behavioral features in Odontophrynidae.

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