

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

Afonso Santiago de Oliveira Meneses^{1,3}, Bruno Alessandro Augusto Peña Corrêa^{2,3}

¹Laboratório de Herpetologia, Departamento de Zoologia, Museu Paraense Emílio Goeldi. CEP 66040-170, Belém, Pará, Brazil.

²Laboratório de Anatomia Comparativa de Vertebrados, Instituto de Biologia, Universidade de Brasília. Caixa Postal 04357. CEP 70910-900, Brasília, DF, Brazil.

³Laboratório de Fauna e Unidades de Conservação, Departamento de Engenharia Florestal, Faculdade de Tecnologia, Universidade de Brasília. Caixa Postal 04357. CEP 70919-970 Brasília, DF, Brazil.

Recibida: 06 Junio 2020

Revisada: 22 Junio 2020

Aceptada: 20 Julio 2020

Editor Asociado: C. Borteiro

doi: 10.31017/CdH.2020.(2020-039)

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,

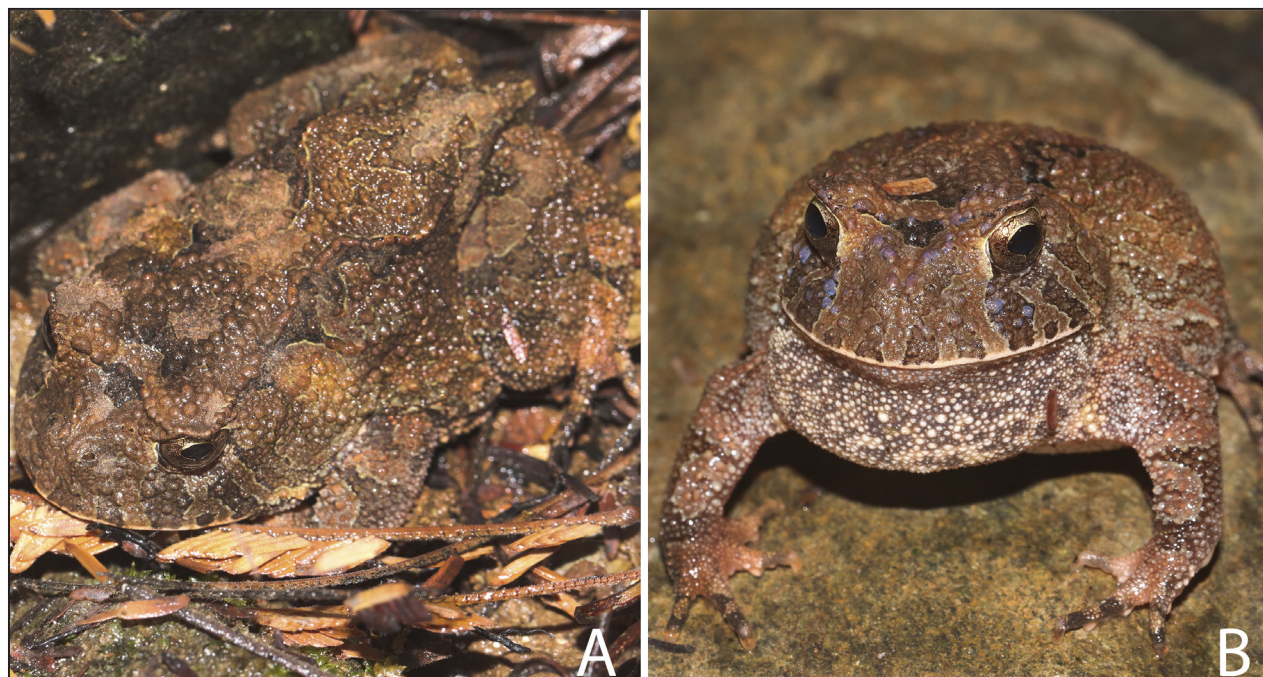


Figure 1. Defensive displays of *Proceratophrys goyana*, crouching down (A) and puffing up the body, while discharging skin secretions (B) (Photos by ASOM).

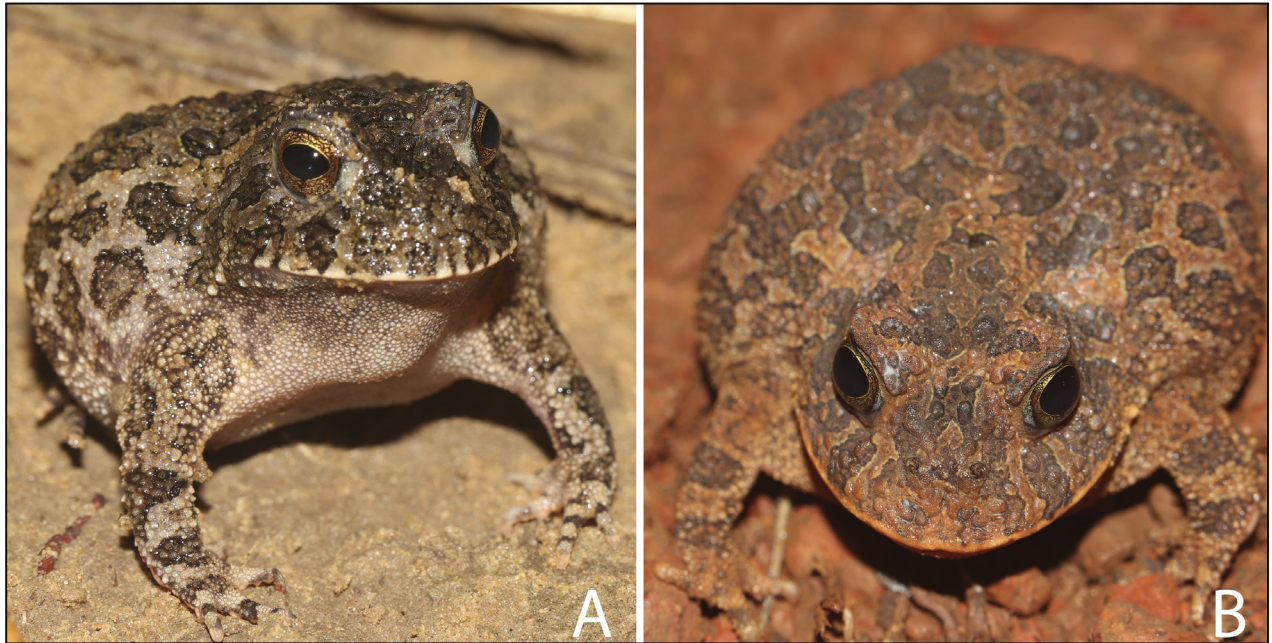


Figure 2. Defensive displays of *Proceratophrys vielliardi*, puffing up the body (A) and puffing up while discharging secretions (B) (Photos by ASOM).

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, 1986 |
| <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.

Acknowledgements

We are grateful to Nathalie Citeli for comments on the earlier version of the manuscript. We also thank Fazenda Água Limpa for support during fieldwork. The manuscript was also improved by suggestions made by Cuadernos de Herpetología reviewers.

Literature cited

- Ávila, R.W.; Pansonato, A. & Strussmann, C. 2012. A new species of *Proceratophrys* (Anura: Cycloramphidae) from western Brazil. *Zootaxa* 2980: 20-28.
- Borteiro, C.; Rosset, S.D.; Kolenc, F.; Barasso, D.A.; Lescano, J.N. & Baldo, D. 2018. Stereotyped defensive behaviour in frogs of the genus *Odontophrynus* (Amphibia: Anura: Odontophrynidae). *Current Herpetology* 37: 172-179.
- Brandão, R.A. & Araújo, A.F.B. 2001. A herpetofauna associada às matas de galeria no Distrito Federal: 561-604. In: Ribeiro, J.F., Fonseca, C.E.L. & Sousa-Silva, J.C. (eds.), Cerrado: Caracterização e Recuperação de Matas de Galeria. Embrapa press, Brasília.
- Brandão, R.A.; Vaz-Silva, W.; Caramaschi, U. & Franço, R.D. 2012. New distribution records of *Proceratophrys vielliardi* Martins & Giaretta 2011 (Amphibia, Anura, Cycloramphidae). *Herpetology Notes* 5: 223-225.
- Brandão, R.A.; Caramaschi, U.; Vaz-Silva, W. & Campos, L.A. 2013. Three new species of *Proceratophrys* Miranda-Ribeiro 1920 from the Brazilian Cerrado (Anura, Odontophrynidae). *Zootaxa* 3750: 321-347.
- Carvalho, G.; Meneses, A.S.O.; Queiroz, P.P. & Brandão, R.A. 2020. Multiple mating and oviposition behaviour of *Proceratophrys goyana* (Anura: Odontophrynidae) in the Brazilian Cerrado. *Cuadernos de Herpetología* 34: 83-87
- Cooper, W.E.; Caldwell, J.P. & Vitt, L.J. 2008. Effective crypsis and its maintenance by immobility in *Craugastor* frogs. *Copeia* 2008: 527-532.
- Costa, P.N.; Silva-Soares, T. & Bernstein, L.B. 2009. Defensive behaviour of *Proceratophrys boiei* (Wied-Neuwied, 1824) (Amphibia, Anura, Cycloramphidae). *Herpetology Notes* 2: 227-229.
- Duellman, W.E. & Trueb, L. 1994. Biology of Amphibians. John Hopkins University Press, Baltimore.
- Edmunds, M. 1974. Defence in animals: A survey of anti-predator defences. Burnt Mill, New York.
- Ferreira, R.B.; Lourenço-de-Moraes, R.; Zocca, C.; Duca, C.; Beard, K.H. & Brodie Jr, E.D. 2019. Antipredator mechanisms of post metamorphic anurans: a global database and classification system. *Behavioral Ecology and Sociobiology* 73: 69.
- Frost, D.R. 2020. Amphibian Species of the World: an Online Reference. Version 6.0. Available at: <http://research.amnh.org/vz/herpetology/amphibia/>. Last access: May 26, 2020.
- Giaretta, A.A.; Bernarde, P.S. & Kokobum, M.N.C. 2000. A new species of *Proceratophrys* (Anura: Leptodactylidae) from the Amazon Rain Forest. *Journal of Herpetology* 34: 173-178.
- Greenbaum, E. 2004. The influence of prey-scent stimuli on predatory behaviour of the North American copperhead *Agkistrodon contortrix* (Serpentes: Viperidae). *Behavioral Ecology* 15: 345-350.
- Kolenc, F.; Borteiro, C.; Baldo, D.; Ferraro, D.P. & Prigioni, C. 2009. The tadpoles and advertisement calls of *Pleurodema bibroni* Tschudi and *Pleurodema kriegi* (Müller), with notes on their geographic distribution and conservation status (Amphibia, Anura, Leiuperidae). *Zootaxa* 1969: 1-35.
- Loebmann, D. & Haddad, C.F.B. 2010. Amphibians and reptiles from a highly diverse area of the Caatinga domain: Composition and conservation implications. *Biota Neotropica* 10: 227-256.
- Lourenço-de-Moraes, R., & Lourenço-de-Moraes, R. 2012.

- Proceratophrys avelinoi*, *Cycloramphus acangatan*. Defensive Behavior. *Herpetological Review* 43: 324-325.
- Maffei, F. & Ubaid, F.K. 2016. Defensive behavior of *Odontophrynus americanus* (Duméril & Bibron, 1841). *Neotropical Biology and Conservation* 11: 195-197.
- Marchisin, A. & Anderson, J.D. 1978. Strategies employed by frogs and toads (Amphibia, Anura) to avoid predation by snakes (Reptilia, Serpentes). *Journal of Herpetology* 12: 151-155.
- Mângia, S. & Santana, D.J. 2013. Defensive behavior in *Rhinella granulosa* (Spix, 1824) (Amphibia: Anura: Bufonidae). *Herpetology Notes* 6: 45-46.
- Mângia, S. & Garda, A.A. 2015. Distress call and defensive display of *Proceratophrys cristiceps* (Muller, 1883) (Amphibia, Anura, Odontophrynidae). *Herpetology Notes* 8: 11-14.
- Martins, L.C. & Giaretta, A.A. 2011. A new species of *Proceratophrys* Miranda-Ribeiro (Amphibia: Anura: Cycloramphidae) from central Brazil. *Zootaxa* 2880: 41-50.
- Martins, L.C. & Giaretta, A.A. 2013. Morphological and acoustic characterization of *Proceratophrys goyana* (Lissamphibia: Anura: Odontophrynidae), with the description of a sympatric and related new species. *Zootaxa* 3750: 301-320.
- Mira-Mendes, C.V.; Ruas, D.S.; Castro, I.; Solé, M. & Baumgarten, J.E. 2016. Defensive behaviour in the Bahia forest frog *Macrogenioglottus alipioi* Carvalho, 1946 (Anura: Odontophrynidae), with a review of the stiff-legged posture. *Herpetology Notes* 9: 91-94.
- Moura, M.R.; Santana, D.J.; Mângia, S. & Feio, R.N. 2010. *Proceratophrys melanopogon*. Defensive behaviour. *Herpetological Review* 41: 479.
- Peixoto, M.A.A.; Mângia, S.; Rodrigues, R. & Santana D.J. 2013. Defensive behaviour in *Proceratophrys renalis* (Miranda-Ribeiro, 1920) (Anura, Odontophrynidae). *Herpetology Notes* 6: 479-430.
- Ribeiro, J.F. & Walter B.M.T. 2008. As principais fitofisionomias do bioma Cerrado: 151-212. In: Sano, S.M. & Almeida S.P. (eds.), Cerrado: Ambiente e Flora. Embrapa press, Brasília.
- Santoro, G.R.C.C. & Brandão, R.A. 2014. Reproductive modes, habitat use, and richness of anurans from Chapada dos Veadeiros, central Brazil. *North-Western Journal of Zoology* 10: 365-373.
- Sazima, I. 1978. Convergent defensive behaviour of two leaf-litter frogs of southeastern Brazil. *Biotropica* 10: 158.
- Teixeira Jr, M., Amaro, R.C., Recoder, R.S., Dal Vechio, F., Rodrigues, M.T. 2012. A new dwarf species of *Proceratophrys* Miranda-Ribeiro, 1920 (Anura, Cycloramphidae) from the highlands of Chapada Diamantina, Bahia, Brazil. *Zootaxa* 3551: 25-42.
- Toledo, L.F. & Zina, J.P. 2004. *Proceratophrys boiei* (Smooth Horned Toad). Defensive behavior. *Herpetological Review* 35: 375.
- Toledo, L.F. & Haddad, C.F.B. 2009. Colors and some morphological traits as defensive mechanisms in anurans. *International Journal of Zoology* 2009: 1-12.
- Toledo, L.F.; Sazima, I. & Haddad, C.F.B. 2011. Behavioural defences of anurans: an overview. *Ethology, Ecology & Evolution* 23: 1-25.
- Wells, K.D. 2007. The ecology and behaviour of amphibians. The University of Chicago Press, Chicago.
- Weygoldt, P. 1986. Beobachtungen zur Ökologie und Biologie von Fröschen an einem neotropischen Bergbach. *Zoologische Jahrbücher. Abteilung für Systematik, Ökologie und Geographie der Tiere* 113: 429-454.

