

## SHORT COMMUNICATION

# Field record of aestivation with formation of cocoon in the frog *Leptodactylus fuscus* (Anura: Leptodactylidae) in a semiarid region of northeastern Brazil

Iardley Cícero Gomes Varjão and Leonardo Barros Ribeiro

Centro de Conservação e Manejo de Fauna da Caatinga (CEMAFAUNA), Universidade Federal do Vale do São Francisco. Av. José de Sá Maniçoba s/n, Centro, 56304-917, Petrolina, PE, Brazil. E-mail: [leonardo.ribeiro@univasf.edu.br](mailto:leonardo.ribeiro@univasf.edu.br).

**Keywords:** anurans, Caatinga Biome, cocoon-forming frogs, fossorial behavior.

**Palavras-chave:** anuros, bioma Caatinga, comportamento fossorial, rãs formadoras de casulos.

The Caatinga is a semiarid region of northeastern Brazil characterized by high solar radiation, high annual average temperatures, and scarce to irregular rainfall (Prado 2003). Because amphibians have permeable skin, they are sensitive to water loss, and their larvae usually are dependent on access to bodies of water (Wygoda 1984). Given these biotic and abiotic conditions, many anurans are endemic to the Caatinga (Napoli *et al.* 2011, Cavalcanti *et al.* 2014). It follows that most anurans occurring in the seemingly unfavorable conditions of the Caatinga have mechanisms to protect themselves from desiccation in the surface soil (Prado 2003, Navas *et al.* 2004). Anurans employ three main strategies to avoid drying effects of the surface soil; they can burrow deep in the soil, accumulate urea in body fluids, and form cocoons

(Shoemaker *et al.* 1969, Shoemaker 1988, Cartledge *et al.* 2006, Reynolds *et al.* 2010). Typically, most Caatinga anurans also have additional adaptations. For example, in *Proceratophrys cristiceps* (Müller, 1884 “1883”) and *Corythomantis greeningi* Boulenger, 1896, the dermal layer of the skin is calcified (co-ossified with the deeper bone), a cutaneous adaptation that reduces evaporative water loss; similarly, lipid secretion glands prevent desiccation in *Pithecopus hypochondrialis* (Daudin, 1800) (Navas *et al.* 2004). Other species, such as *Pleurodema diplolister* (Peters, 1870) and *Physalaemus* spp. that lack both cutaneous adaptations and a deep dormant state, are found hiding but attentive. Finally, some non-aestivating anurans, such as in *Rhinella* spp., have behavioral adaptations to cope with dehydration; in these toads, activity is opportunistic and the anurans retreat to shelter when the soil becomes too dry. This behavior is particularly evident in juvenile toads (Navas *et al.* 2004).

Received 28 August 2017

Accepted 19 February 2018

Distributed June 2018

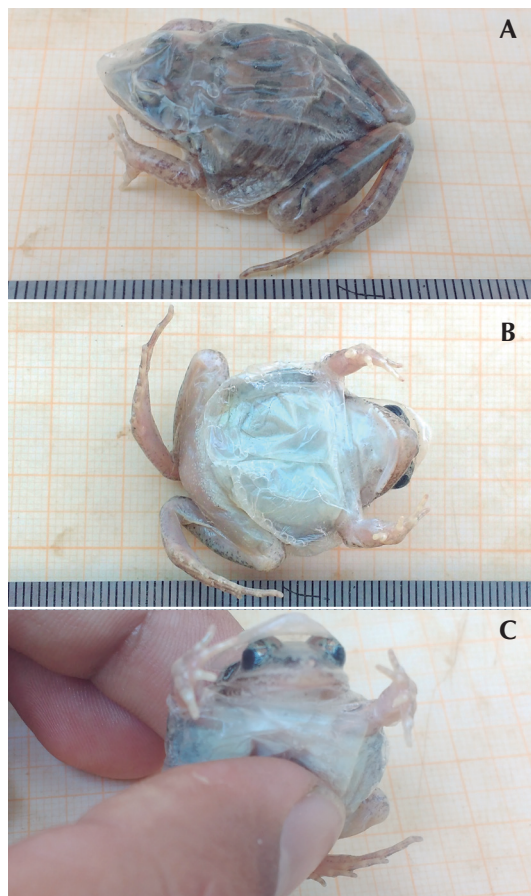
*Leptodactylus fuscus* (Schneider, 1799) is a small frog (adults reaching 60 mm SVL) occurring from Panama, through South America east of the Andes to Argentina, from seal level up to 1700 m a.s.l. (Heyer 1978). However, genetic evidence indicates that there are several cryptic species within *L. fuscus* (Camargo *et al.* 2006). This frog is terrestrial and nocturnal, and can be found in savannas, pastures, marshes, degraded forests, and urban environments. It is common in the Caatinga in various habitats, even in highly modified environments (Vieira *et al.* 2007). Male *L. fuscus* begin to vocalize at the beginning of the rainy season and reproduction occurs in small burrows near temporary or permanent ponds (Lucas *et al.* 2008, Ribeiro *et al.* 2013). Herein, we report aestivation with formation of cocoon in *L. fuscus* from a semiarid region of northeastern Brazil, a finding that has not been previously reported in Leptodactylidae.

During a period of heavy drought in 2015, faunal rescue activities were conducted by personnel from the Centro de Conservação e Manejo de Fauna da Caatinga (CEMAFAUNA) in conjunction with Project to Integrate the Rio São Francisco (PISF) with the hydrographic basins of northern northeast Brazil. On 13 November 2015, an aestivated *L. fuscus* was collected in the municipality of São José de Piranhas in the state of Paraíba (Boa Vista Reservoir; 07°05'53.4" S, 38°36'43.6" W). This area lies in the Sertão Paraibano mesoregion, which exhibits a hot semiarid climate (BSh), according to the Köppen climate classification system. Average temperatures in the region range from 26–28°C and the average annual rainfall is between 500 and 800 mm; the predominant vegetation is hyperxerophillic, shrubby-arboreal, characteristic of Caatinga *sensu stricto* (Velloso *et al.* 2002, Prado 2003).

The frog was found after a backhoe loader had excavated the soil from a site where the vegetation previously had been removed for construction of the Boa Vista Reservoir, and about 700 m from a temporary pond. The soil at this site had a superficial layer of decomposing

wood, and the frog was found at approximately 100–150 cm depth. On examination of the frog, we observed that the skin was modified and resembled a cocoon. The cocoon had an opening in the rostral region and a viscous liquid inside (Figure 1). After 5 min, the frog left the resting state and began to breathe more intensely, at which point the eyes opened and the frog began to rub itself and perform leaping movements tried to get rid of the cocoon. The frog was placed in a closed receptacle, where it resumed its resting state inside the cocoon. After about 1.5 h, the frog was euthanized and deposited, still in its cocoon, in the Coleção Herpetológica of the Museu de Fauna da Caatinga (MFCH 4088) at the CEMAFANA in Petrolina, in the state of Pernambuco.

The formation of cocoons from the *stratum corneum* is one of the survival strategies employed by some frog species subject to adverse conditions of arid and semiarid ecosystems (Reynolds *et al.* 2011). The cocooned *Leptodactylus fuscus* was discovered during the dry season when there had been successive days without rain. This cocoon seems to act as physical barrier preventing water loss (Reynolds *et al.* 2010). Cocoon formation characterizes various species that live in arid areas of Africa (pyxicephalid *Pyxicephalus adpersus* Tschudi, 1838), North America [hylid *Smilisca fodiens* (Boulenger, 1882)] (Loveridge and Withers 1981, Ruibal and Hillman 1981), Australia [limnodynastid *Neobatrachus aquilonius* Tyler, Davies, and Martin, 1981; pelodyradids *Ranoidea australis* (Gray, 1842); and *Cyclorana platycephala* (Günther, 1873)] (Cartledge *et al.* 2006, 2008, Tracy *et al.* 2007), and South America [ceratophryids *Lepidobatrachus llanensis* Reig and Cei, 1963 and *Ceratophrys ornata* (Bell, 1843)] (McClanahan *et al.* 1976, 1983). Given the distant relationships of these lineages, it seems likely that ability to form such cocoon evolved independently in the various groups and may be more widespread among aestivating anurans than currently thought (Ruibal and Hillman 1981, Faivovich *et al.* 2014). With



**Figure 1.** *Leptodactylus fuscus* from the Caatinga of northeastern Brazil exhibiting a modified skin cocoon during aestivation in the dry season. Dorsal view of the cocoon (A), ventral view where fluid accumulation is observed (B), and view of the anterior opening of the cocoon (C). Photos by Iardley Varjão.

regard to ceratophryids, cocoon production is probably ancestral and remained even in species that secondarily adapted to humid areas (Faivovich *et al.* 2014), such as *Ceratophrys ornata* and *C. aurita* (Raddi, 1823) (Canziani and Cannata 1980, Bastos and Abe 1998).

Cocoon production in *Leptodactylus fuscus* deserves further investigation. In fact, Abe and Garcia (1990) observed that *L. fuscus* becomes

dormant during the dry season in southeastern Brazil (Atlantic Forest) without formation of cocoon, but maintains a favorable osmotic gradient to prevent loss of water to the soil. Given the characteristics of the Caatinga Biome, the osmoregulatory process for aestivating anurans probably is one of the most extreme physiological challenges for resident anurans in contrast to anuran osmoregulation in humid ecosystems (e.g., Atlantic Forest). Because *L. fuscus* is widely distributed in Brazil with suspected cryptic species (Camargo *et al.* 2006), we encourage more integrative and comparative studies to determine the factors involved on the evolution of aestivation in this assemblage.

**Acknowledgments.**—We thank the Ministério da Integração Nacional for the financial support, the Centro de Conservação e Manejo de Fauna da Caatinga for technical assistance, and Samuel C. Gomides and two anonymous referees for revising the manuscript. Collecting permits (042/2007, 125.r/2010 and 95/2012, processes number 02001.003112/2007-12 and 02001.003718/94-54) were granted by Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA). 🐸

## References

- Abe, A. S. and L. S. Garcia. 1990. Changes in body fluids of the frog *Leptodactylus fuscus* during aestivation (Anura, Leptodactylidae). *Revista Brasileira de Biologia* 50: 243–247.
- Bastos, R. P. and A. S. Abe. 1998. Dormancy in the Brazilian horned toad *Ceratophrys aurita* (Anura, Leptodactylidae). *Ciência e Cultura* 50: 68–69.
- Camargo, A., R. O. de Sá, and W. R. Heyer. 2006. Phylogenetic analyses of mtDNA sequences reveal three cryptic lineages in the widespread neotropical frog *Leptodactylus fuscus* (Schneider, 1799) (Anura, Leptodactylidae). *Biological Journal of Linnean Society* 87: 325–341.
- Canziani, G. A. and M. A. Cannata. 1980. Water balance in *Ceratophrys ornata* from two different environments. *Comparative Biochemistry and Physiology* 66: 599–603.

- Cartledge, V. A., P. C. Withers, K. A. McMaster, G. G. Thompson, and S. D. Bradshaw. 2006. Water balance of field-excavated aestivating Australian desert frogs, the cocoon-forming *Neobatrachus aquilonius* and the non-cocooning *Notadennicholisi* (Amphibia: Myobatrachidae). *Journal of Experimental Biology* 209: 3309–3321.
- Cartledge, V. A., P. C. Withers, and S. D. Bradshaw. 2008. Water balance and arginine vasotocin in the cocooning frog *Cyclorana platycephala* (Hylidae). *Physiological and Biochemical Zoology* 81: 43–53.
- Cavalcanti, L. B. Q., T. B. Costa, G. R. Colli, G. C. Costa, F. G. R. França, D. O. Mesquita, C. N. S. Palmeira, N. Pelegrín, A. H. B. S. Soares, D. B. Tucker, and A. A. Garda. 2014. Herpetofauna of protected areas in the Caatinga II: Serra da Capivara National Park, Puaúf, Brazil. *Check List* 10: 18–27.
- Faivovich J., L. Nicoli, B. L. Blotto, M. O. Pereyra, D. Baldo, J. S. Barrionuevo, M. Fabrezi, E. R. Wild, and C. F. B. Haddad. 2014. Big, bad, and beautiful: phylogenetic relationships of the horned frogs (Anura: Ceratophryidae). *South American Journal of Herpetology* 9: 207–227.
- Heyer, R. W. 1978. Systematics of the *fuscus* group of the frog genus *Leptodactylus* (Amphibia, Leptodactylidae). *Natural History Museum of Los Angeles County Science Bulletin* 29: 1–85.
- Loveridge, J. P. and P. C. Withers. 1981. Metabolism and water balance of active and cocooned African bullfrogs *Pyxicephalus adspersus*. *Physiological Zoology* 54: 203–214.
- Lucas, E. M., C. A. Brasileiro, H. M. Oyamaguchia, and M. Martins. 2008. The reproductive ecology of *Leptodactylus fuscus* (Anura, Leptodactylidae): new data from natural temporary ponds in the Brazilian Cerrado and a review throughout its distribution. *Journal of Natural History* 42: 2305–2320.
- McClanahan, L. L., R. Ruibal, and V. H. Shoemaker. 1983. Rate of cocoon formation and its physiological correlates in a ceratophryd frog. *Physiological Zoology* 56: 430–435.
- McClanahan, L. L., V. H. Shoemaker, and R. Ruibal. 1976. Structure and function of the cocoon of a ceratophryd frog. *Copeia* 1976: 179–185.
- Napoli, M. F., C. A. G. Cruz, R. O. Abreu, and M. L. Del-Grande. 2011. A new species of *Proceratophrys* Miranda-Ribeiro (Amphibia: Anura: Cycloramphidae) from the Chapada Diamantina, state of Bahia, northeastern Brazil. *Zootaxa* 3133: 37–49.
- Navas, C. A., M. M. Antoniazzi, and C. Jared. 2004. A preliminary assessment of anuran physiological and morphological adaptation to the Caatinga, a Brazilian semi-arid environment. *International Congress Series* 1275: 298–305.
- Prado, D. E. 2003. As Caatingas da América do Sul. Pp. 3–74 in I. R. Leal, M. Tabarelli, and J. M. C. Silva (eds.), *Ecologia e Conservação da Caatinga*. Recife. Editora da UFPE.
- Reynolds, S. J., K. A. Christian, and C. R. Tracy. 2010. The cocoon of the fossorial frog *Cyclorana australis* functions primarily as a barrier to water exchange with the substrate. *Physiological and Biochemical Zoology* 83: 877–884.
- Reynolds, S. J., K. A. Christian, C. R. Tracy, and L. B. Hutley. 2011. Changes in body fluids of the cocooning fossorial frog *Cyclorana australis* in a seasonally dry environment. *Comparative Biochemistry and Physiology, Part A* 160: 348–354.
- Ribeiro, L. B., R. F. D. Coelho, M. Gogliath, C. C. M. Moura, P. M. A. G. Reis, M. A. Matos, K. Souza, L. M. N. Menezes, and A. P. G. Tavares (eds.). 2013. *Guia de Herpetofauna do Campus de Ciências Agrárias da UNIVASF*. Petrolina. Editora e Gráfica Franciscana. 62 pp.
- Ruibal, R. and S. Hillman. 1981. Cocoon structure and function in the burrowing hylid frog, *Pteromohyla fodiens*. *Journal of Herpetology* 15: 403–408.
- Shoemaker, V. H. 1988. Physiological ecology of amphibians in arid environments. *Journal of Arid Environments* 14: 145–153.
- Shoemaker, V. H., L. McClanahan Jr., and R. Ruibal. 1969. Seasonal changes in body fluids in a field population of spadefoot toads. *Copeia* 1969: 585–591.
- Tracy, C. R., S. J. Reynolds, L. J. McArthur, C. R. Tracy, and K. A. Christian. 2007. Ecology of aestivation in a cocoon-forming frog, *Cyclorana australis* (Hylidae). *Copeia* 2007: 901–912.
- Velloso, A. L., V. S. B. Everardo, E. V. S. B. Sampaio, and F. G. C. Pareyn (eds.). 2002. *Ecorregiões: Propostas para o Bioma Caatinga*. Recife. Associação Plantas do Nordeste e Instituto de Conservação Ambiental The Nature Conservancy do Brasil. 76 pp.
- Vieira, W. L. S., C. Arzabe, and G. G. Santana. 2007. Composição e distribuição espaço-temporal de anuros do Cariri Paraibano, nordeste do Brasil. *Oecologia Brasiliensis* 11: 383–396.
- Wygoda, M. L. 1984. Low cutaneous evaporative water loss in arboreal frogs. *Physiological Zoology* 57: 329–337.

Editor: Tamí Mott