

Predator-prey: predation strategies of *Leptodactylus macrosternum* and defensive behavior of *Leptodactylus fuscus*

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Received: 2 February 2022 / Accepted: 4 May 2022 / Published online: 31 May 2022

Abstract

Congeneric predation between two *Leptodactylus* species was recorded and information was collected on the predation strategy of *L. macrosternum* and the defensive behavior and distress call of *L. fuscus*. The entire predation event lasted about 90 min and ended when predator tore integument of the prey's ventral region, facilitating swallowing. The distress call description was based on a record of 40 s containing seven calls, consisting of a pulsatile and harmonically complex structure composed of two notes. Although the batrachophagy is well-documented in the genus *Leptodactylus*, descriptions of predatory and defensive behaviors are not fully described. Thus, the defensive behaviors observed here made predation a physiologically taxing event, while we look at how the predator can use various mechanisms to overcome prey defensive behaviors.

Keywords: Anura; congeneric species; Leptodactylidae; distress call.

Predador-presa: estratégias de predação de *Leptodactylus macrosternum* e comportamento defensivo de *Leptodactylus fuscus*

Resumo

A predação congênica entre duas espécies de *Leptodactylus* foi registrada além de reunidas informações sobre as estratégias de predação de *L. macrosternum* e o comportamento defensivo e canto de socorro de *L. fuscus*. Todo o evento de predação durou cerca de 90 minutos e terminou após o predador ter rasgado o tegumento da presa, facilitando a deglutição. A descrição do canto de socorro foi baseada em um registro de 40 s contendo sete cantos, consistindo em uma estrutura pulsátil e harmonicamente complexa composta por duas notas. Embora a batracofagia esteja bem documentada no gênero *Leptodactylus*, a descrição dos comportamentos predatórios e defensivos não são completamente descritos. Assim, os comportamentos defensivos observados aqui tornaram a predação um evento fisiologicamente desgastante, enquanto observamos como o predador pode usar vários mecanismos para superar os comportamentos defensivos da presa.

Palavras-chave: Anura; espécies congênicas; Leptodactylidae; canto de socorro.

Amphibians serve different functional roles within ecosystems (Hocking & Babbitt, 2014), acting as predators and prey for invertebrates or vertebrates (Toledo, Ribeiro, & Haddad, 2007; Jobe, Montaña, & Schalk, 2019). In relation to vertebrates, there are several reports of batrachophagy and even cannibalism among anuran amphibians (Forti, Sousa, & Costa-Campos, 2017; Carrillo, Ferreira, & Santana, 2019; Costa & Trevelin, 2020). The leptodactylids currently comprises 232 species (Frost, 2021) that mainly feed on insects and crustaceans (Teles *et al.*, 2014), but are also recognized in some cases to act both as predators and prey for other amphibians (Carrillo *et al.*, 2019; Queiroz, Couto, & Miguel, 2019; Costa & Trevelin, 2020).

While predators develop strategies to maximize efficiency in capturing food (Preisser, Orrock, & Schmitz, 2007), prey develop defensive mechanisms to prevent or hinder the predation process (Toledo, Sazima, & Haddad, 2011; Sena *et al.*, 2021). Some animals have developed different defensive strategies, for example thanatosis, defensive vocalizations, and postures, such as body inflation and body raising (Toledo *et al.*, 2011; Toledo *et al.*, 2015; Sena *et al.*, 2021). Among the defensive vocalizations, the most frequent during the predation events is known as distress call, which is characterized by a high-pitched whistle, usually emitted with the mouth open, not only by males but also by females and juveniles (Toledo, Tozetti, & Zina, 2005) when they are being preyed upon.

Herein, we record a congeneric predation between two species of Leptodactylidae and provide information on the predation strategies of *Leptodactylus macrosternum* Miranda-Ribeiro, 1926 and the defensive behavior of *L. fuscus* (Schneider, 1799) including the description of its distress call.

During fieldwork carried out on January 7, 2021, near the Açude Joana (4°25'39.2"S, 41°28'01.3"W, datum WGS84; 547 m a.s.l.), municipality of Pedro II, state of Piauí, Northeast region of Brazil, we observed an adult female *L. macrosternum* preying on an adult female *L. fuscus*. The predation began around 20:30 h when we were attracted by the prey's distress call. The individuals were found on the ground at the margins of the municipality's access road (PI-216) amidst marginal vegetation, about 7 m from the nearest body of water.

The recording of the predation was done by video in MP4 format using a cell phone Xiaomi Redmi Note 8 Pro. For analysis of acoustic parameters, we extracted the audio from the original video using software Audacity v. 2.0.3 (<http://audacity.sourceforge.net/>) with a sampling rate of 44.1 kHz and 32-bit size. To reduce background noise, we applied a 600 Hz and 36 dB high-pass filter. Calls were analyzed in Raven Pro 1.6.1 software (Center for Conservation Bioacoustics, 2019) using the settings: Window Type = Hanning, Window Size = 512 samples; 3 dB Filter Bandwidth = 124 Hz; Overlap = 90% (locked), Hop Size = 1.16 ms, DFT Size = 512 samples, Grid Spacing = 86.1 Hz. Note and call terminologies follow Köhler *et al.* (2017) using a note-centered approach. Sound figure was produced using the packages Seewave 2.1.6 (Sueur, Aubin, Simonis, 2008) and tuneR 1.3.3 (Ligges, Krey, Mersmann, Schnackenberg, 2017), in R 4.0.4 64-bit (R Core Team, 2021), with the following settings: window = Hanning; FFT size = 512 samples; FFT overlap = 90%; color scale = 30 dB relative (Figure 2). The video and audio were deposited at Fonoteca Neotropical Jacques Vielliard at the University in Campinas, Brazil (ZUEC-VID 976 and FNJV_0050594, respectively).

The *L. macrosternum* captured *L. fuscus* by its left hind limb while the right limb remained free (Figure 1A). In an attempt to escape, the *L. fuscus* turned its body, with its belly facing up, and its right hind limb was partially swallowed (Figure 1B). After a few minutes, the *L. fuscus* released its right limb and kept it extended, making swallowing difficult (Figure 1C). At times the *L. macrosternum* positioned itself with its body and limbs slightly extended and often used its forelimbs to push the prey towards its mouth. Throughout the predation event, the *L. fuscus* displayed two anti-predatory behaviors including maintaining an inflated body (Figure 1D) and emitting several distress calls. After about 90 min, the predator grabbed the two hind limbs of the prey. In one of the attempts to position it, the predator tore the integument of the prey's ventral region, which ceased all anti-predatory behaviors, allowing the complete swallowing of the individual (Figure 1D-E). The whole predation event lasted about 90 min, ending at 22:00 h. The *L. macrosternum* escaped after predation.

The distress call description was based on a 40 s recording containing seven calls. The distress call consists of a pulsatile and harmonically complex structure (with about 15 harmonics), similar to a high-pitched moan emitted with the mouth open, composed of two notes with an average duration of 1.094 ± 0.083 s (0.964 - 1.210 s) and inter-call interval of

3.570 ± 1.897 s (0.865 - 6.776 s). The note A is slightly longer and has an average duration of 0.479 ± 0.049 s (0.382 - 0.538 s) and the note B has an average duration of 0.340 ± 0.037 s (0.284 - 0.397 s). The distress call has a minimum frequency of 0.626 ± 0.078 kHz (0.547 - 0.729 kHz) and maximum frequency of 17.056 ± 0.074 kHz (16.856 - 17.130 kHz). The dominant frequency in the note A was 5.405 ± 1.004 kHz (3.876 - 6.460 kHz) and the dominant frequency in the note B was 4.823 ± 0.847 kHz (3.790 - 6.202 kHz).



Figure 1. Predation of *Leptodactylus fuscus* by *L. macrosternum*, municipality of Pedro II, Piauí State, Brazil. A - *L. fuscus* grasped by the left hind limb; B - right hind limb partially swallowed; C - right hind limb extended; D - *L. macrosternum* trying to position its prey; E - rupture of the prey ventral tegument; and F- end of predation. Photos: Claylton A. Costa.

Although distress calls are well-documented in different families and genera of anurans (Toledo & Haddad, 2009), recording them in nature is difficult. However, the recording of the distress call can be done in an induced manner, with the researcher themselves handles and induces the individual to call (Toledo & Haddad, 2009; Forti & Costa-Campos, 2020). In addition, the development of increasingly sophisticated equipment, such as digital cameras and cellular phones, makes it easier to record audio and video in the field (Forti & Costa-Campos, 2020; Dorado-Rodrigues, Campos, Santos, Pansonato, & Striessmann, 2012). The *L. fuscus* distress call has been described previously by Toledo and Haddad (2009) based on five manually induced distress calls, however, we documented several structural differences.

Although the two calls are similar with respect to the number of harmonics and the minimum and maximum frequencies, we observed a composed call (two notes) with call duration and dominant frequency higher than recorded by those authors.

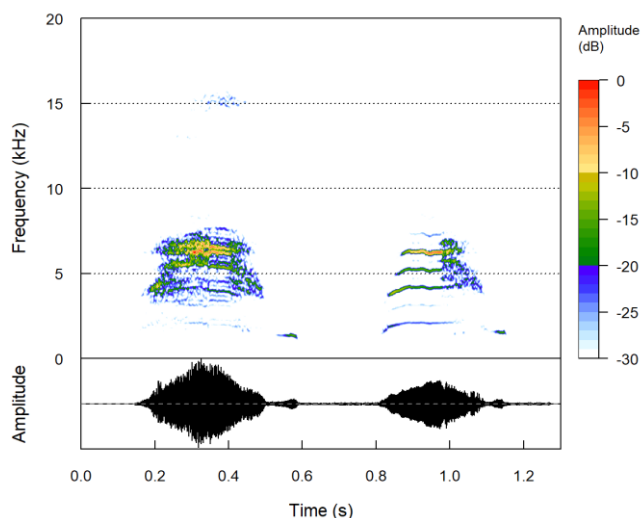


Figure 2. Spectrogram and sonogram of the distress call of *Leptodactylus fuscus*, municipality of Pedro II, state of Piauí, Brazil.

Among the many facets of the social behavior of anurans, their vocalization abilities have been studied, but the function and effectiveness of defensive vocalizations are generally unknown (Toledo & Haddad, 2009). Dourado-Rodrigues *et al.* (2012) also reported differences between the acoustic parameters in the distress call of *L. macrosternum* (= *L. chaquensis*) when it is handled or preyed upon, reinforcing the idea that the degree of distress may cause individual variation in distress call (Sousa, Baía, & Campos, 2016). Despite the differences observed here in relation to the acoustic parameters described by Toledo and Haddad (2009) (composed call vs simple call), the *L. fuscus* distress call is similar to other leptodactylid species, corroborating the modulated and harmonically complex nature of the neotropical frogs distress call (Toledo & Haddad, 2009; Forti & Costa-Campos, 2020).

Although batrachophagy is well documented in the genus *Leptodactylus* (Forti *et al.*, 2017; Carrillo *et al.*, 2019; Costa & Trevelin, 2020), the description of the predatory and defensive behaviors of the individuals involved is still poorly known. The predation of *L. fuscus* by *L. macrosternum* (= *L. chaquensis*) had already been recorded by Costa and Trevelin (2020) in the state of Goiás, Center-West region of Brazil, but the prey did not emit any defensive vocalizations. However, it inflated its body and extended its right limb. The posture of the predator during swallowing was very similar to that recorded here (slightly distended body), except for the ventral integument rupture of the prey that enabled the predator to swallow the prey completely. These behaviors are both novel in regards to the predatory and defensive behaviors of *Leptodactylus*.

We documented an additional case of congeneric predation by *L. macrosternum* (Sousa *et al.*, 2016; Forti *et al.*, 2017; Carrillo *et al.*, 2019; Queiroz *et al.*, 2019; Costa & Trevelin, 2020). Although this species is considered an opportunistic predator, other leptodactylids appear to be important elements

in its diet. It is important to mention that we only found the anurans due to the distress call emission, confirming that this type of vocalization can contribute to the prey's escape by attracting other animals, such as other predators of the species involved (Gollmann & Hödl, 1986) or even curious humans and domestic animals. In addition, defensive behaviors (e.g., inflated body and outstretched limbs) make predation a stressful event, showing that the use of different strategies results in greater chances of escaping a predator's attack (Toledo *et al.*, 2011). Therefore, the defensive behaviors observed here made predation a physiologically taxing event, while we look at how the predator can use various mechanisms to overcome prey defensive behaviors.

Acknowledgments

The authors are grateful to Instituto Chico Mendes de Conservação da Biodiversidade for a collection license (#61838-4/21). CAC hanks the Universidade Estadual de Santa Cruz – UESC for the fellowship (#88887.485357/2020-20 - PPG-UESC), LRU thanks the Fundação de Amparo à Pesquisa e ao Desenvolvimento Científico e Tecnológico do Maranhão for the fellowship (#BM-01016/21), and SCMA thanks the Universidade Estadual do Maranhão for fellowship (#01/2020 PPG-UEMA).

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