First records of visual displays in *Scinax x-signatus* (Spix, 1824) (Anura: Hylidae) in Northeastern Brazil

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The communication process involves the transfer of information from a sender to a receiver through specifically designed signals. These signals have evolved to manipulate the receiver's behavior and may occur at intra and interspecific levels (Bradbury & Vehrencamp, 1998; Hödl & Amézquita, 2001; Rendall et al., 2009). In anurans, communication can occur through chemical, acoustic, seismic or visual means (see Narins, 1990; Giasson & Haddad, 2006; Woodley, 2014). Acoustic communication is the most documented, occurring in almost all anurans and performed mainly through males' vocalizations (Hartmann et al., 2005).

Visual displays are a complementary or alternative form of communication in most anurans, depending on the social context (Amézquita & Hödl, 2004). Although daylight facilitates visual signaling, amphibians are usually nocturnal because it offers less risk of desiccation, lower temperatures, and lower vulnerability to visually oriented predators (Duellman & Trueb, 1986). The use of visual communication at night is considered limited as it can be obscured by vegetation and other ob-

stacles while acoustic sounds can be more easily broadcast (Marler, 1967). Nevertheless, the occurrence of visual communication in many taxa suggests it has evolved independently on multiple occasions and in different environmental conditions (Hödl & Amézquita, 2001).

Records of the use of visual displays as a form of communication in frogs have been documented in several families: Bufonidae, Brachycephalidae, Dendrobatidae, Hylidae, Hylodidae, Leptodactylidae and Phyllomedusidae (see Hödl & Amézquita, 2001; Hartmann et al., 2005; Augusto-Alves et al., 2018; Brasileiro et al., 2020). Here we report the first record of visual communication in the hylid frog *Scinax x-signatus* (Spix, 1824) involving three individuals in a region of Caatinga in the State of Ceará.

At 20h54min on June 24th, 2018, during a night walk in the municipality of Russas (4°51'3.35"S, 38°23'52"W; WGS 84), Ceará, Brazil, we observed three individuals of *S. x-signatus* (two males and one female), perched in a tree near an anthropized area. The specimens were 50 cm above the ground, performing stereotyped behaviors using the forelimbs (see videos in *https://osf.io/v5dpr/*). We also observed an individual of *Corythomantis greeningi* Boulenger, 1896 hidden in a tree hole, and located between the *Scinax* during the events (Fig. 1). We made the audio-visual recordings using a smartphone camera. We used Vegas Pro software to edit the videos, count the visual performances and time the movements. We classified the visual displays according to Hödl & Amézquita (2001) and Hartmann et al. (2005), and we calculated the average duration of the movements performed by each individual.

Movements in two categories of visual displays were identified. The first, arm-waving, consists of extending one arm and waving it in a circular movement, with the arm passing in front of the eyes (Hödl & Amézquita, 2001). The second, limb-lifting, consists of rapid ascending and descending movements of either arm without extending it (Hartmann et al., 2005). The arm-waving movement was performed by male 1 using both arms (n = 12; Table 1). Limb-lifting movements were performed by male 2 (n = 6; Table 1) using both arms and by the female (n = 1) using the right arm. We observed an ordering in the use of limbs by male 1 during the arm-waving display, first using the right arm and then the left arm, ending in what we call an exhibition cycle. We did not observe ordering patterns in the use of limbs to perform limb-lifting movements.

Limb movement is one of the most commonly reported types of visual displays in anurans, reported in several genera (see review in Hödl & Amézquita, 2001;

Hartmann et al., 2005). Movements performed by the forelimbs, such as arm-waving and limb-lifting, are usually associated with agonistic contexts and may occur during aggressive interactions between males (Pombal Jr. et al., 1994; Haddad & Giaretta, 1999; de Sá et al., 2016; Moroti et al., 2017), intersex interactions in courtship events (Pombal et al., 1994; Haddad & Giaretta, 1999; de Sá et al., 2016), interspecific encounters between taxonomically close species or resource competitors (Gerhardt & Schwartz, 1995; Wogel et al., 2004; Hartmann et al., 2005) or even provoked by the presence of human observers (Goutte et al., 2017).

Generally, the result of these interactions will depend on the response sent by the message receiver to the individual who sends the signal (Hödl & Amézquita, 2001). We observed that the limb-lifting movements by male 2 and the female may represent a response signal to the arm-waving movement by male 1, as soon as a display cycle is executed. However, we were unable to identify the behavioral reaction of male 1 to this response due to the absence of other subsequent interactions, such as combat or copulation events (Hödl & Amézquita, 2001). Therefore, we cannot determine to which individual the signal was being addressed.

In the genus *Scinax*, the use of visual signals has been described for *S. eurydice* (Bokermann, 1968), *S. fuscomarginatus* (Lutz, 1925), *S. cardosoi* (Carvalho-e-Silva & Peixoto, 1991), *S. maracaya* (Cardoso & Sazima, 1980), and *S. nasicus* (Cope, 1862), with records of limb-lifting and leg-kicking exhibitions (Hartmann et al., 2005; Toledo & Haddad 2005; Barros & Feio, 2011; Furtado et al., 2017; Moroti et al., 2017). Unlike in diurnal species where daylight can facilitate the message (Richards & James, 1992), the use of visual signals by nocturnal species can be considered limited due to the absence of light (Marler, 1967). Nocturnal hylids of the genus *Litoria* Tschudi, 1838 take advantage of moonlight to communicate through visual signals (Richards & James, 1992). Conversely, Moroti et al. (2017) documented that the display of visual signals in *S. cardosoi* can change in response to light, with signal reproduction being interrupted by direct light projection on the individuals. Our observations demonstrate that this premise may not be valid for *S. x-signatus*, since the visual displays performed by the individuals were not interrupted by light projection during video recording.

Scinax x-signatus is frequently found in urban areas and other anthropic environments (Ferreira et al., 2010). Environmental noise can make it difficult to receive bioacoustic signals, thereby favoring the use of visual signals (Hödl & Amézquita, 2001). Noise pollution

by human actions may be an influential factor in the displays of visual signals in this species. Artificial lighting may also be a possible factor influencing visual displays, since light can favor the use of visual signals in some species (Lindquist & Hetherington 1996; Hartmann et al., 2005). However, more observations and methodological studies are necessary for a better understanding of the types and contexts of use of visual communication in this species.

Our records represent a new type of communication (arm-waving) in the repertoire of visual displays adopted by *Scinax* and the first records for *S. x-signatus*. Thus, it contributes to understanding the methods used for communication by this species, and helps to observe patterns within phylogenetically close groups.

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Table 1. Duration (in seconds) and number of arm waving and limb lifting movements (n) performed by *Scinax x-signatus* in Russas, Ceará, northeastern Brazil. Values are expressed as mean ± standard deviation (SD) and range of movement duration.

	male 1 (arm waving)		**male 2 (limb lifting)**	
limb (n)	right arm (6)	left arm (6)	right arm (3)	left arm (3)
mean ± SD	3.2 ± 0.7	3.6 ± 1.5	0.7 ± 0.2	0.4 ± 0.2
range	[2.3, 4.3]	[2.2, 6.3]	[0.5, 0.9]	[0.2, 0.6]

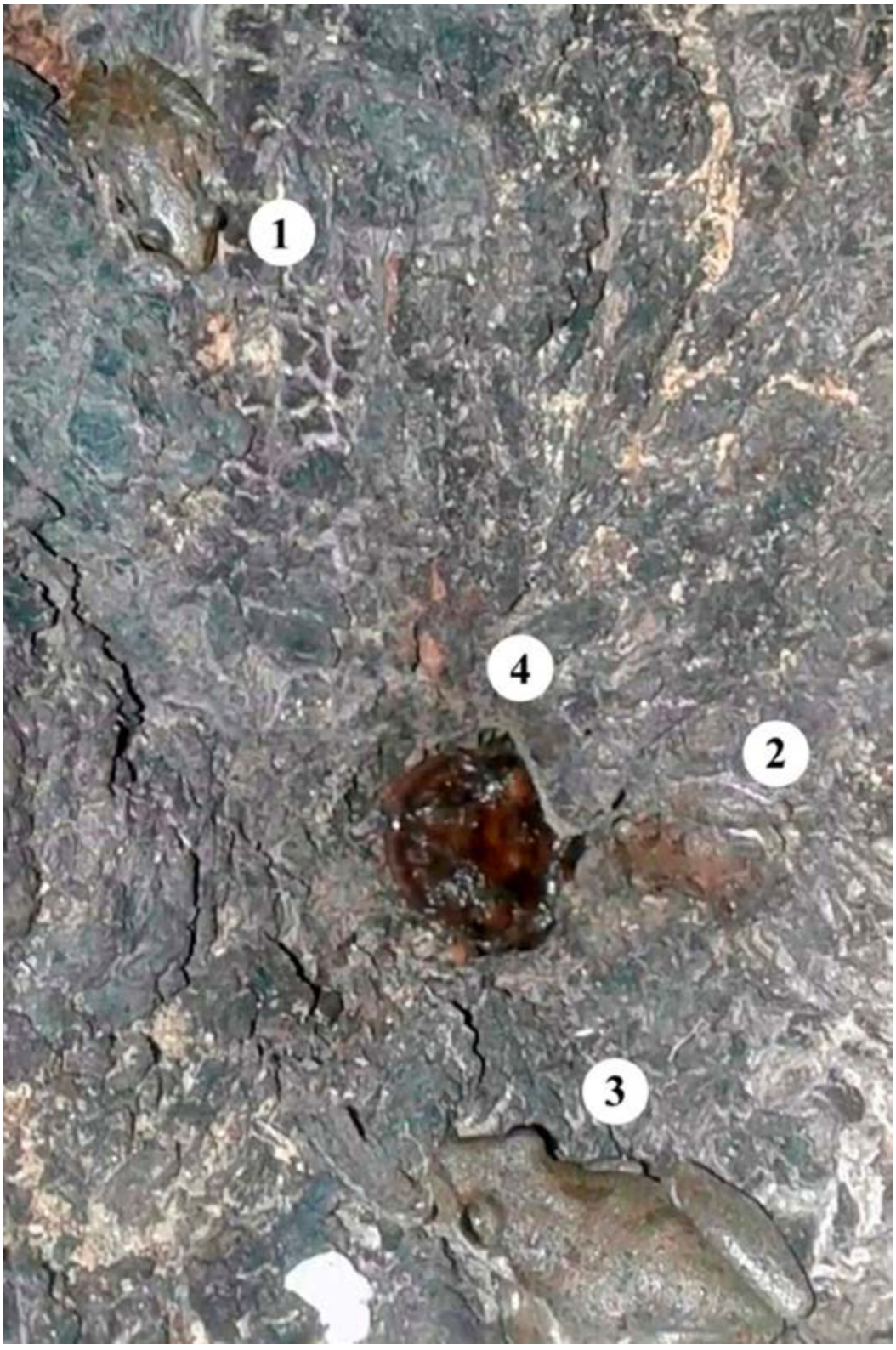

Figure 1. Photograph of the males (1 and 2) and female (3) individuals of *Scinax x-signatus* during visual performances, with the presence of an individual of *Corythomantis greeningi* (4) in Russas, Ceará, northeastern Brazil.