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# Behavioural repertoire and a new geographical record of the torrent frog *Hylodes cardosoi* (Anura: Hylodidae)

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There are 24 currently recognized species in the genus *Hylodes*, which are distributed into Atlantic Forest and some areas of Cerrado from the State of Espírito Santo to State of Rio Grande do Sul, Brazil (Lingnau et al., 2008; Frost, 2011). These frogs are diurnal and have a strict association with fast-water rock streams, where they call on rocks or falling trunks (Nascimento et al., 2001; Lingnau & Bastos, 2007; Silva & Benmaman, 2008). Commonly, the species of *Hylodes* exhibit two kinds of call: the advertisement call and the territorial call (“encounter call” by some authors) (Narvaes & Rodrigues, 2005; Hartmann et al., 2006; Lingnau & Bastos, 2007). In the genus, there appear to exist two main types of advertisement call and *H. cardosoi* and *H. dactylocinus* (both in the *nasus* group) present the more uncommon type, characterized by notes more spaced. The courtship and territorial defences involves a complex combination of sound and visual signals (Haddad & Giaretta, 1999; Hödl & Amézquita, 2001; Pavan et al., 2001; Wogel et al., 2004; Hartmann et al., 2005; Lingnau et al., 2008). According to Haddad & Prado (2005), species of *Hylodes* spawn in streams inside constructed subaquatic chambers.

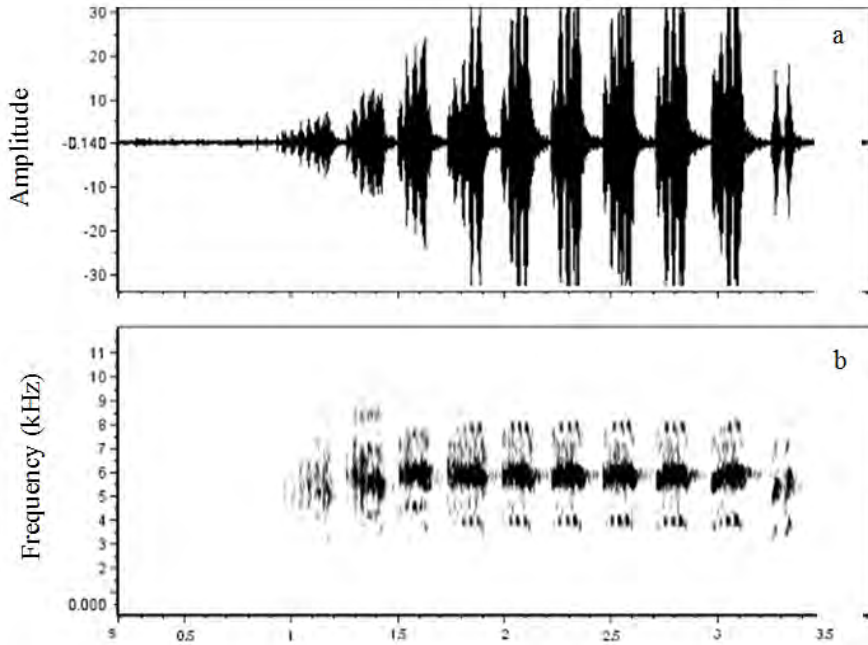
*H. cardosoi* (Lingnau et al., 2008) belongs to *H. nasus* (Lichteistein, 1823) group and was recently described from Morretes municipality, state of Paraná, Brazil (Lingnau et al., 2008). Besides the type-locality, this species occurs in Apiaí, Capão Bonito and Iporanga municipalities, state of São Paulo, southeastern Brazil (Lingnau et

al., 2008).

Herein, we characterize the behavioural repertoire of a non-topotypic population of *H. cardosoi* from Tapiraí, State of São Paulo, southeastern Brazil, including a comparison of its body size and advertisement call with its original description.

## MATERIALS AND METHODS

A population of *H. cardosoi* was observed in fast water streams at the Parque do Zizo, inside Paranapiacaba Mountains, municipality of Tapiraí, São Paulo State, southeastern Brazil (24°00'46"S; 47°48'45"W, 650m elev.). This place is characterized by Atlantic Rain Forest vegetation (Morellato & Haddad, 2000). The climate of the region is warm and wet without drought (Moraes et al., 1999). The field work was carried out between March 2005 and February 2006, with one additional visit in November 2009, totalling 49 days of data collection. The naturalistic observations were made mainly during the day using “animal focal” method (Lehner, 1996). Some nocturnal observations were made to evaluate if the individuals are active at this time. Under natural conditions the calls from six males were recorded using a Marantz PMD660 digital recorder and YOGA EM 9600 directional microphone. The advertisement calls were analyzed and the Waveform and the Spectrograms were made in Cool Edit 96™ (Syntrillium), with 16 bits resolution and FFT size of 1024. The recordings were broadcasted experimentally to



**Figure 1.** (a) Waveform and (b) Spectrogram of *H. cardosoi* advertisement call from Tapiraí, SP. Recorded on 11 November 2009; Water temperature approximately 18°C.

territorial males in order to stimulate the exhibition of territorial behaviours. The visual signals and the reproductive behaviour of *H. cardosoi* individuals were documented with camcorder Sony DCR-HC21 NTSC model.

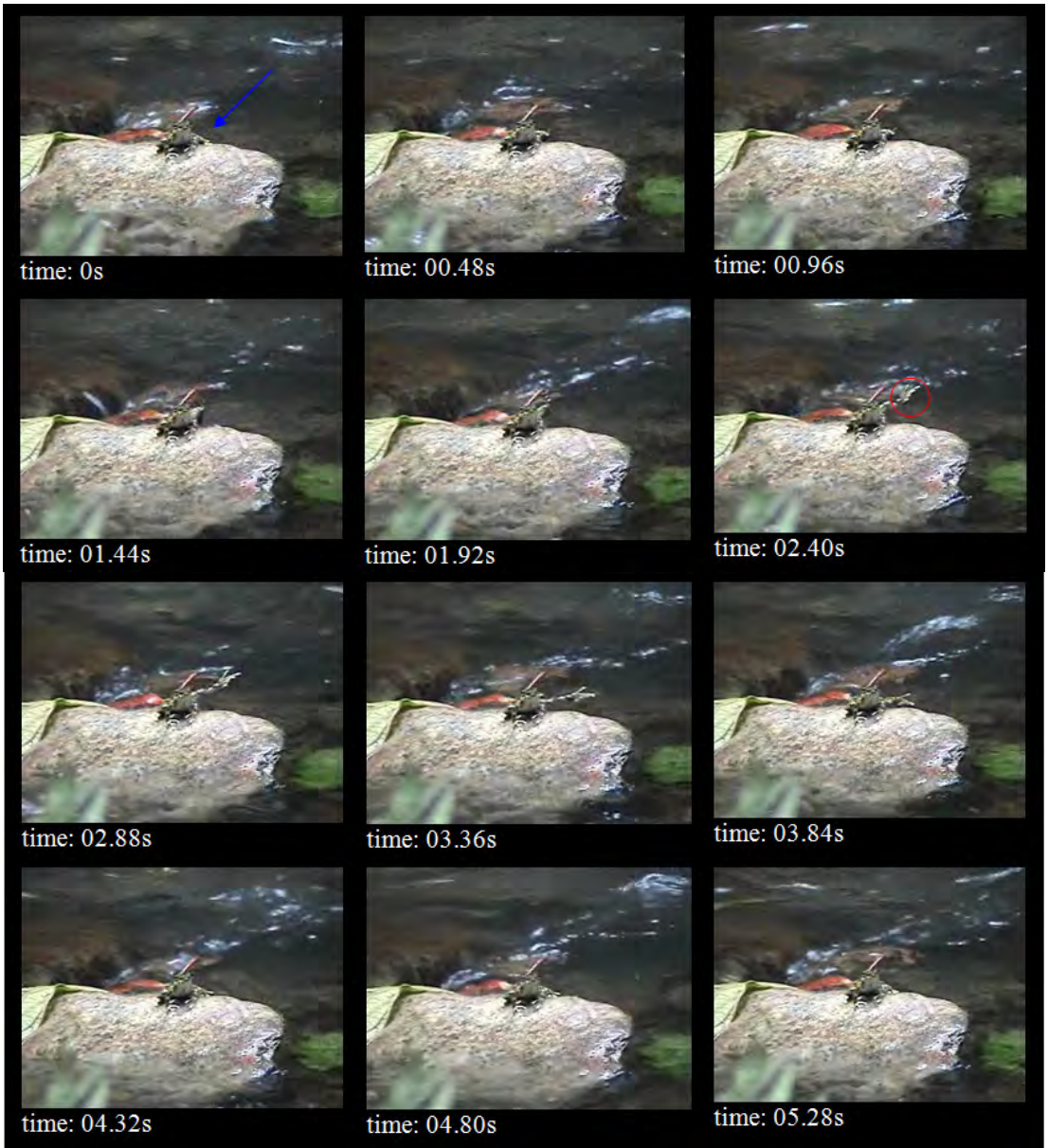
## RESULTS

Our record extends the species distribution at least 50 km northeast from its known distribution. Males call on rocks and falling trunks in streams during the daytime. The calling males were observed throughout the months of data collection. *H. cardosoi* is sympatric with *Crossodactylus caramaschii* Bastos & Pombal, 1995 in most streams of this region. At night we registered individuals resting on leaves at the stream-margins. The advertisement call of *H. cardosoi* from Tapiraí is composed of 3 to 13 notes. The note duration is 0.18 s ( $\pm 0.03$  s; range: 0.12-0.25; N=31). Each note is pulsed with 4 to 7 pulses (N=31 from 6 males). The calls occupy the frequency range between 4.3 and 6.9 kHz, with the main frequency from 4.9 – 6.0 kHz (N=31 from 6 males).

We observed two territorial interactions among

males that involve exhibition of visual signals besides advertisement and territorial call (Table 1). The visual signals were registered in four situations during courtship events and besides males, females were observed exhibiting the foot-flagging on some occasions (Table 1). The play back experiments provoked reactions in territorial males that responded by displaying visual signals and territorial calls (Table 1). The foot-flagging display may be accompanied by advertisement calls simultaneously and has about five seconds of duration (Figure 2).

Sometimes, when displaying, males were seen diving in the water among the rocks then returning to the display location. We define these submerged locations as nests that are visited by males. During pair formation (N=3) that were always observed close to midday (1200hrs) the females approached the territories of males and at about a distance of 60 cm the males performed a series of visual signals. The females may perform the foot-flagging for three or four times, apparently a response to male signals. The foot-flagging performed by females was seen in two courtship events. Then,



**Figure 2.** Movement sequence of foot-flagging displayed by a territorial male of *H. cardosoi* in the municipality of Tapiraí, São Paulo State, Brazil (time expressed in seconds (s)). Blue arrow shows the male on the rock and the red circle shows the foot location during the foot-flagging display.

the males while emitting the territorial call generally approach and touch the females with their hands or snout. After that, the males were always observed guiding the females to the submerged nest whilst still using advertisement

calls. We did not find the egg masses.

#### DISCUSSION

The diurnal calling activity on rocks amidst streams registered to *H. cardosoi* (this study and Lingnau

Behaviours	Description	Advertisement	Social context	
			Territorial	Courtship
Advertisement call	Figure 1	♂	♂	
Body raising	Elevating the body by totally extending the arms and partially the legs		♂	♂
Foot-flagging	Raising one hind leg, extending it slowly out and back in an arc above the substrate level, and returning it to body side	♂♀	♂	♂♀
Foot-flagging with toe wave movement	Same foot-flagging movement with toe vibrating at maximum extension feet	♂	♂	♂
Leg kicking*	It seems that the animal is “kicking the air” laterally or backwards	♂	♂	♂
Leg stretching with one leg	Stretching a hind leg rapidly to substratum level	♂		♂
Leg stretching with two legs	Stretching both the hind legs rapidly to substratum level	♂		♂
Limb lifting	Rapid up-and-down movements of an arm	♂	♂	
Territorial call	Short call with spaced notes emitted (not detailed here)		♂	♂

\*New behaviour recorded to the genus *Hylodes*.

**Table 1.** Summary of behavioural displays of *H. cardosoi* from municipality of Tapiraí, São Paulo State, Brazil. The behavioural categories follow the descriptions given by Hödl & Amézquita (2001) and Hartmann et al. (2005). The symbols ♂♀ indicate the sexes that perform the behaviour.

et al., 2008) is common to other species of *Hylodes* (Almeida-Gomes et al., 2007; Lingnau & Bastos, 2007). The advertisement call of *H. cardosoi* is similar to *H. dactylocinus* because both have more spaced notes than the advertisement call of other *Hylodes* sp. This similarity of call-properties between *H. cardosoi* and *H. dactylocinus* may help to elaborate a new phylogenetic hypothesis to the genus based in bioacoustic traits. A detailed comparison of *H. cardosoi* advertisement call properties with other *Hylodes* species is provided by Lingnau et al. (2008). The advertisement call of *H. cardosoi* from Tapiraí is about 200 Hz higher than the call of the toptotypical population (Lingnau

et al., 2008). Probably this feature is associated with the difference on body size from these two populations (Table 2).

Lingnau et al. (2008) observed males of *H. cardosoi* displaying visual signals, for example body raising and foot-flagging. Here we extend the list of display behaviours of *H. cardosoi* complemented with social context information. One visual signal recorded to *H. cardosoi* (leg kicking) is new to the genus *Hylodes*. The foot-flagging exhibited by females described in the present paper is probably unknown to any anuran species. Something unclear from our data is why males display territorial calls in an aggressive



Locality	Mean of Snout-Vent Length (mm)	
	♂	♀
Tapiraí, SP	32.2 (S.D. = 1.3, range = 30.9-34.0, N=7)	35.5 (S.D. = 0.7, range = 34.3-36.5, N=4)
Morretes, PR	40.4 (S.D. = 2, range = 35.6-44.1, N=32)	42.4 (S.D. = 2.6, range = 36.7-46.5, N=31)

**Table 2:** Body size of two populations of *H. cardosoi*, southeastern Brazil. For the last population (Morreates, PR), data are from Lingnau et al. (2008).

context during the pair formation? We believed that, initially, males may have problems in recognizing females, making visual and tactile signals important mechanisms in identifying competitors or the available females to reproduce with. Once a female is not able to reproduce she is regarded as a competitor in the male territory. Thus, the foot-flagging employed by females makes sense for communication between sexes during courtship. However, further work is needed to confirm this hypothesis. Visual signals are known in other species of *Hylodes* (Haddad & Giaretta, 1999; Hartmann et al., 2005; Narvaes & Rodrigues, 2005; Wogel et al., 2004). Hödl & Amézquita (2001) explored a hypothesis of a relationship between of visual signals with diurnality and noisy environments. For these conditions, visual signals seem to be favoured as an evolutionary trait and *H. cardosoi* with a diverse set of visual displays support this view.

Although we did not find any egg clutches of *H. cardosoi*, the reproductive behaviour described in the present paper is similar to *H. dactylocinus* (Narvaes & Rodrigues, 2005) and agrees with previous knowledge about reproductive mode indicated by Haddad & Prado (2005) for *Hylodes*. This study contributes to our knowledge of the natural history of *H. cardosoi*, which represents a step in the effort to understand the evolution of complex behaviours in the Hylodidae.

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