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ORIGINAL ARTICLE

Vocalization of *Hylodes meridionalis* (Mertens 1927) (Anura, Hylodidae) in Rio Grande do Sul, Brazil, with comments on nocturnal calling in the family Hylodidae

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We describe the advertisement and territorial calls of *Hylodes meridionalis* for the first time and provide observations on nocturnal calling activity for this species. The advertisement call has 36–82 harmonic notes, with duration of 2.71–5.69 s and dominant frequency on the third harmonic. Advertisement calls are separated by large intervals varying from 18.7 to 44.7 s. The territorial call has 1–3 notes, with duration of 0.039–0.567 seconds, and dominant frequency also on the third harmonic. Territorial calls are emitted at a much higher repetition rate than the advertisement call, with intervals of 1.1–1.6 s between each call. Frogs of the genus *Hylodes* are known to call mainly during the day, but for *H. meridionalis* nocturnal calling was observed on various occasions, and could occur regularly until two hours after sunset, or sporadically along the night.

Descrevemos os cantos de anúncio e territorial de *Hylodes meridionalis* pela primeira vez e fornecemos observações sobre a atividade noturna de vocalização para esta espécie. O canto de anúncio tem 36–82 notas harmônicas, com duração de 2,71–5,69 segundos e frequência dominante no terceiro harmônico. Há grandes intervalos entre os cantos de anúncio, de 18,7–44,7 segundos. O canto territorial tem 1–3 notas, com duração de 0,039–0,567 segundos, e frequência dominante também no terceiro harmônico. Cantos territoriais são emitidos a uma taxa de repetição muito mais elevado do que o canto de anúncio, com intervalos de 1,1–1,6 segundos entre cada canto. As espécies do gênero *Hylodes* são conhecidas por vocalizar principalmente durante o dia, mas machos de *H. meridionalis* foram observados em atividade de vocalização noturna em várias ocasiões, sendo que podem vocalizar regularmente até duas horas após o pôr do sol, ou esporadicamente ao longo da noite.

Keywords: Atlantic Forest; southern Brazil; Crossodactylus; advertisement call; territorial call

Introduction

Frogs of the genus *Hylodes* occur along small forested mountain streams in the Brazilian Atlantic Forest (Haddad and Giaretta 1999; Pombal et al. 2002). They are known to be diurnal, and males are easily observed during the day vocalizing from rocks close to the water. Individuals are wary and escape with a few jumps into the water torrents when disturbed (Lutz 1930; Lingnau and Bastos 2007).

Currently 24 species are known in the genus *Hylodes*, arranged in four species groups, as recognized by Heyer (1982): the *H. lateristrigatus* group is the most diverse group, currently composed of 18 species; the *H. glaber* and the *H. mertensi* groups include only a single species each; and the *H. nasus* group contains four species (Da Silva and Benmaman 2008; Lingnau et al. 2008). *Hylodes meridionalis* (Mertens 1927) was first allocated in the *H. nasus* group by Heyer (1982), but Pombal et al. (2002) reassigned this species to the *H. lateristrigatus* group.

Hylodes meridionalis was described from the Municipality of São Francisco de Paula, in the State of Rio Grande do Sul, southern Brazil, occurring in the northeastern region of this state and in the extreme South of the neighboring State of Santa Catarina, at elevations of 400–1000 m (Mertens 1927; Garcia and Segalla 2010). During field activities in Rio Grande do Sul, we recorded advertisement and territorial calls and made observations on nocturnal calling activity of *H. meridionalis*.

Materials and methods

We obtained call recordings of *H. meridionalis* from the Pró-Mata reserve (see Kwet et al. 2010) in the municipality of the type locality, São Francisco de

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Paula, and from Itati (a nearby municipality, 50 km east from São Francisco de Paula). Vocalizations were recorded with a Sony ECM microphone coupled to a Marantz PMD-222 cassette tape recorder (Itati) or with a Sennheiser microphone system K6 with ME 66 module coupled to a Sony WM-D6C tape recorder (São Francisco de Paula). For recording advertisement calls, we approached and directed the microphone toward the calling male at a distance of around 80 cm. Territorial calls were obtained from a single male spontaneously emitting territorial calls after our approximation. After playing back advertisement calls, other males also emitted this territorial call. We analyzed 22 advertisement calls from six males, and nine territorial calls from one male.

Calls were digitized with a sampling frequency of 22 kHz and 16-bit resolution. Sonograms were made with the software Avisoft-SASLab Light with fast Fourier transformation of 256 points, 75% overlap, and window hamming. Dominant frequencies and oscillograms were obtained with Cool Edit 96 with fast Fourier transformation of 1024 points. Call terminology follows Heyer et al. (1990), as also used by Lingnau and Bastos (2007) and Lingnau et al. (2008).

Voucher specimens were deposited in the herpetological collection of the Museu de Ciências e Tecnologia da Pontifícia Universidade Católica do Rio Grande do Sul (MCP 9531–9536), and recordings are deposited at the Laboratório de Biologia Geral, Universidade Tecnológica Federal do Paraná, Campus Francisco Beltrão.

Results

The most frequent call emitted by males was the advertisement call, formed by long, high-pitched, whistled trills (Figure 1). The call has a harmonic structure, with the dominant frequency on the third harmonic, at 3.9–4.9 kHz. Fundamental frequency lies around 1.4 kHz, and a second harmonic is found around 2.5 kHz. The duration of this call varied from 2.71 to 5.69 s, with 36–82 notes. The intervals between single calls varied from 18.7 to 44.7 s.

The second call type we recorded was the territorial call, with a similar structure, but much shorter than the advertisement call, consisting of only 1–3 notes (Figure 2). The duration of the territorial call was 0.039–0.567 s, and the dominant frequency was also on the third harmonic, at 4.4–4.9 kHz. The territorial calls were emitted at a much higher call repetition rate, with intervals of 1.1–1.6 s between each call.

On various occasions we heard males of *H. meridionalis* vocalizing at night. In November 2005, at the municipality of Itati, we observed several males vocalizing during daylight, and they continued calling until two hours after dusk. On various occasions at Pró-Mata, we heard single males of *H. meridionalis* vocalizing until midnight. On 8 December 1995, at 01:00 h at night, six advertisement calls from one male were recorded (recording AK 3A05, air temperature 18°C); on 5 December 1997, at 01:30 h at night, six advertisement calls from another male were recorded (recording AK 8A12, air temperature 14°C). Generally, the individuals calling at night presented higher intervals between their more sporadic calls; the recorded males had call intervals of 40–50 s.

Discussion

Although the advertisement call of *H. meridionalis* was informally referred to as a "long trill with short, high-pitched, quickly repeated notes" by Kwet et al. (2010), it has not been analyzed or formally described. In most species of *Hylodes*, the advertisement calls are known to have their dominant frequencies and highest energies on the third harmonic (Haddad and Giaretta 1999; Lingnau and Bastos 2007). However, exceptions have been reported by Hartmann et al. (2006) for *H. phyllodes*, where the dominant frequency was found on the second harmonic, and by Lingnau et al. (2008) for *H. cardosoi*, where on some calls the second and the third harmonics presented about the same energy amount. Likewise, in some species of *Crossodactylus*, which are closely related to *Hylodes* and present a similar diurnal calling behavior, the dominant frequency of the advertisement call was found on the second and/or third harmonic (Pimenta et al. 2008).

Many authors have argued that the dominant frequency in torrent living frogs as *Hylodes* species should be the third harmonic so that it lies beyond the frequency of the rushing water (Haddad and Giaretta 1999; Lingnau and Bastos 2007). However, Hartmann et al. (2006), Pimenta et al. (2008), and Lingnau et al. (2008) demonstrated for several species of *Hylodes* and *Crossodactylus* that, although the dominant frequency was not the third harmonic, the highest call energy was concentrated beyond the noise produced by the rushing water of the torrent streams. This allows a free frequency channel for acoustic communication in these frogs.

Territorial calls are known for several species of *Hylodes*, but for a few of them we are also aware of calls in different social contexts (Haddad and Giaretta 1999; Hartmann et al. 2006). The territorial calls are structurally similar to the advertisement calls, but characterized by a substantially lower number of notes, higher call repetition rates and sometimes with a squeaky note at the end of the whistling call.

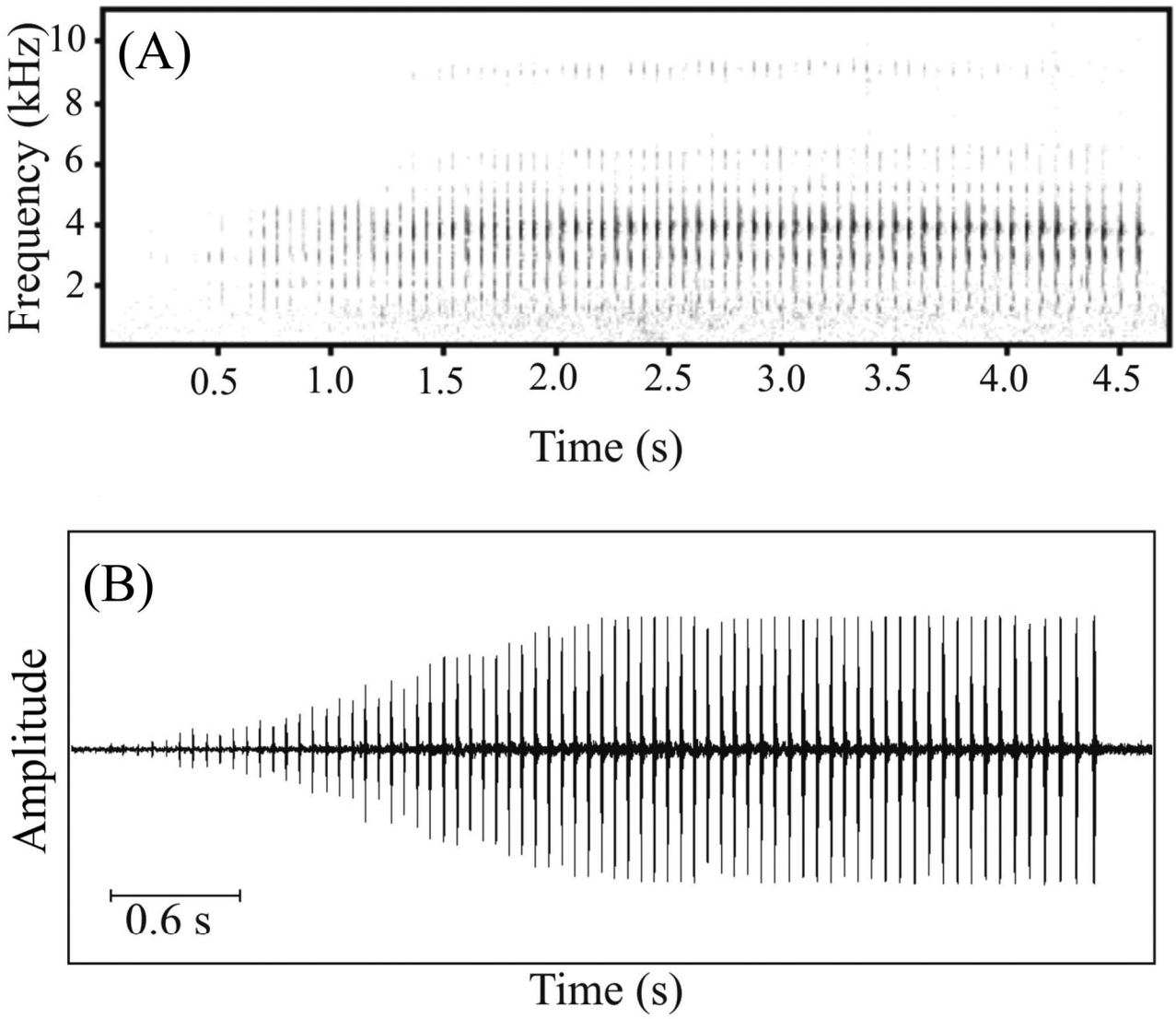

Figure 1. Sonogram (A) and oscillogram (B) of the advertisement call of *Hylodes meridionalis*. Recorded on 1 March 2006 at São Francisco de Paula, Rio Grande do Sul, Brazil. Air temperature 20.2°C.

Until recently species of the genus *Hylodes* and *Crossodactylus* have been known as exclusively diurnal frogs (Bastos and Pombal 1995; Haddad et al. 1996; Nascimento et al. 2001; Narvaes and Rodrigues 2005; Hartmann et al. 2006; Lingnau and Bastos 2007; Pimenta et al. 2008), and the possibility of nocturnal calling for these partly visually communicating frogs seemed to be implausible.

For the genus *Crossodactylus*, there are some reports of nocturnal activity, but these observations included only foraging activity, without detection of nocturnal calling (Heyer et al. 1990). Almeida-Gomes et al. (2007) did not observe nocturnal activity when studying males of *C. gaudichaudii*, and Jordão-Nogueira et al. (2006) suggested exclusively diurnal calling in males of *C. aeneus*. However, the generalization of exclusive diurnal calling activity in this genus had recently to be amended, when Caldart et al. (2010) found that, although *C. schmidti* was mainly active during the day, the males also showed calling activity at night. Moreover, Caldart et al. (2011) described the advertisement call of *C. schmidti* based on vocalizations which have been exclusively recorded at night, between 19:30 and 05:00 h.

Regarding the genus *Hylodes*, several authors observed individuals at night only resting on leaves (Heyer et al. 1990; Lingnau and Bastos 2007). Hatano et al. (2002) did not notice nocturnal calling when studying a population of *H. fredi* (as *H. phyllodes* in their study, see also Canedo and Pombal 2007) over two years. Heyer et al. (1990) and Alencar et al. (2012) cited occasional nocturnal calling for *H. phyllodes*,

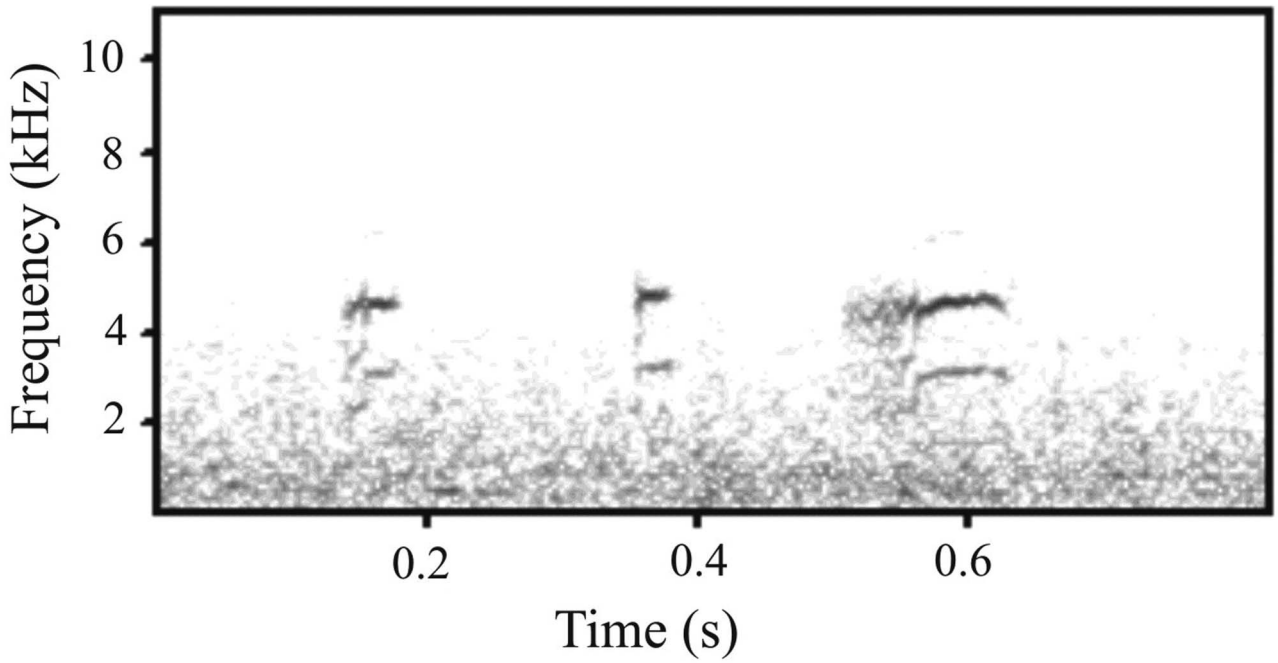

Figure 2. Sonogram of the territorial call of *Hylodes meridionalis*. Recorded on 20 November 2005 at Itati, Rio Grande do Sul, Brazil. Air temperature 22.4°C.

and *H. amnicola* was reported to call during the day including dusk by Pombal et al. (2002). Da Silva and Benmaman (2008) described a new species (*H. perere*) that occasionally called at night, besides diurnal calling activity. However, our observations of males of *H. meridionalis* calling at night, various hours after dusk, are the first record for a species in this genus with regular nocturnal calling activity.

Nocturnal calling in some species of *Crossodactylus* and *Hylodes* might be caused by a mixture of different variables, such as photoperiod, light intensity, habitat complexity, and air temperature. *Hylodes meridionalis* is the southernmost species in the genus, occurring at the highest latitudes, so the variables related to this latitude, e.g. low temperature or specific photoperiod traits, might be responsible for nocturnal calling. But more detailed studies, like those of Hatano et al. (2002) and Almeida-Gomes et al. (2007), are needed to evaluate the environmental factors affecting calling activity in *H. meridionalis*.

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