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The advertisement call of *Gastrotheca chrysostricta* Laurent, 1976 (Anura: Hemiphractidae)

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The genus *Gastrotheca* Fitzinger, 1843 currently harbors 75 species (Frost 2020). These marsupial frogs have a broad latitudinal distribution range in Central and South America, from Costa Rica southward to Argentina (Duellman 2015). The advertisement call features as the pulse structure, call duration, and repetition pulse rate are used by researchers to recognize the species of *Gastrotheca* (Duellman 2015). The availability of call descriptions is also crucial for recognizing these species with secretive life habits and implementing long-term passive acoustic monitoring programs (Vaira *et al.* 2011; Akmentins *et al.* 2014).

There are three endemic species of the genus *Gastrotheca* registered in the ecoregion of Yungas Andean forests in northwestern Argentina: *Gastrotheca christiani* Laurent, 1967; *Gastrotheca gracilis* Laurent, 1969; and *Gastrotheca chrysostricta* Laurent, 1976. These species occur mainly in allopatry (detailed map in Akmentins *et al.* 2012), except for one dubious registry of a sympatric occurrence of *G. christiani* and *G. chrysostricta* in Baritú National Park (Laurent *et al.* 1986; IUCN 2020). These species are at the forefront of conservation efforts in the country due to their high threatened status (Akmentins *et al.* 2012; Vaira *et al.* 2018). This is the particular case of the endangered *G. chrysostricta* (the Baritú's Marsupial Frog) that was recently rediscovered after 25 years without registries in the wild (Akmentins *et al.* 2018; IUCN 2020). Like many aspects of the natural history of the Baritú's Marsupial Frog, its advertisement call is also unknown.

Herein, we describe the advertisement call of *Gastrotheca chrysostricta* based on recordings made in the locality where the species was rediscovered in 2018 (Akmentins *et al.* 2018). Furthermore, we compare the advertisement call of *G. chrysostricta* with the available calls in the literature of the other two related species of *Gastrotheca* from Argentina and one species from southern Bolivia.

We carried out field campaigns on 31 August 2018 and 21 September 2019, in Baritú National Park (22°33'46.8" S 64°45'7.8" W; 1468 m a.s.l.), Salta Province, Argentina. We recorded frogs' vocalizations with a Marantz PMD 661 MKII digital recorder and a directional Sennheiser ME66 microphone protected by a foam windscreen. The microphone was positioned at a distance of 1 to 1.5 m from the calling individuals to avoid call saturation. The recordings were built in an uncompressed WAV format with a 16-bit resolution and a sampling rate of 44100 Hz. After all the recordings, we measured the air temperature 5 cm above the ground with a TES 1312 digital thermometer (precision of 0.1° C). When possible, we measured the snout-vent length (SVL) of the vocalizing male using a Mitutoyo Absolute Digimatic digital caliper (0.1 mm of precision). One voucher specimen was deposited in the herpetological collection of Fundación Miguel Lillo, Tucumán, Argentina (FML 30266), and the analyzed advertisement calls of two specimens were deposited in the bioacoustic collection of Laboratorio de Genética Evolutiva "Claudio Juan Bidau", Instituto de Biología Subtropical (CONICET-UNaM), Misiones, Argentina (LGE-B 0362 corresponds to FML 30266, and LGE-B 0363 corresponds to one non-vouchered individual).

We analyzed ten calls of each individual using the Raven Pro v. 1.5 software (Center for Conservation Bioacoustics 2014). Call analyzes were made under the following settings of the software: Fast Fourier Transformation of 512 points and Hanning window; all other settings were set to the software default. For call description we adopted the call-centered approach of Köhler *et al.* (2017), and their acoustic terminology and definitions. The temporal parameters were directly measured from the oscillogram and the values of spectral traits were obtained through the frequency analysis tool of Ra-

ven Pro (Peak Frequency function). Call feature values are presented as the mean \pm standard deviation (minimum–maximum). Sound figures were generated in the seewave package v.2.0.2 (Sueur *et al.* 2008) of R software v. 4.0.2 (R Core Team 2020), with FFT of 512 points resolution, Hanning window and 85% overlap.

We compared the advertisement call of *Gastrotheca chrysosticta* with the published descriptions of the calls of *G. christiani* and *G. gracilis* from Argentina (available at Vaira *et al.* 2011; Akmentins *et al.* 2014), and with three descriptions of the call of *Gastrotheca piperata* Duellman & Köhler, 2005 from southern Bolivia (available at De la Riva *et al.* 1995; Duellman & Köhler 2005; Sinsch & Juraske 2006).

We recorded the vocalizations of four individuals. The SVL of three recorded individuals was 34.1 ± 0.2 mm (34–34.3 mm). Two individuals were found calling under the detached bark of fallen trunks, and two were calling hidden inside rock crevices. Recordings were made between 17:40 h and 22:35 h, and the air temperature varied from 8 °C to 11 °C. Two of these males were calling in a full chorus (those recorded in 2018), and the other two males were calling isolated without nearby competitor males.

The advertisement call of *Gastrotheca chrysosticta* is a long trill composed of 15 to 29 regularly repeated pulses, with amplitude modulation (Fig. 1). The call also has a slight upward frequency modulation (Fig. 1). Table 1 shows a summary of the temporal and spectral features of the advertisement call of *G. chrysosticta*.

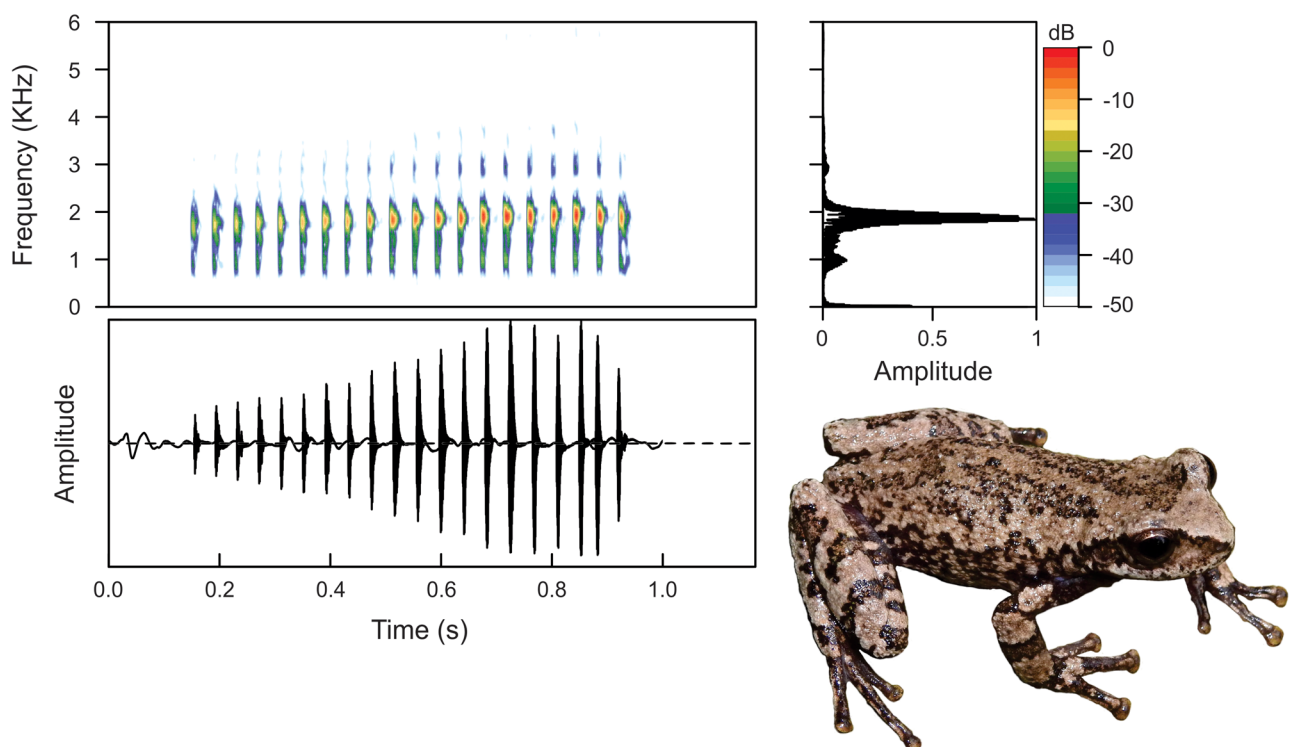


FIGURE 1. Audiospectrogram (upper left), oscillogram (lower left), and power spectrum (upper right) of the advertisement call of *Gastrotheca chrysosticta* from Baritú National Park, Salta Province, Argentina (Air temperature = 10 °C; snout-vent length = 34 mm; LGE-B 0363).

Compared with the other two species of *Gastrotheca* from Argentina (Table 1), the advertisement call of *G. chrysosticta* differs from the geographic closest (even provably sympatric) *G. christiani* in the temporal parameters as the call duration, number of pulses per call and pulse rate. Regarding the allopatric *G. gracilis*, there is a great overlap with the ranges of both calls' temporal and spectral features. It is worth to mention that the mean value of the dominant frequency in *G. chrysosticta* is lower than in *G. christiani* and higher than in *G. gracilis*. Except for the dominant frequency range, the call duration reported by Duellman & Köhler (2005), and the inter-call interval reported by Sinsch & Juraske (2006), most of the temporal features of the call of *G. piperata* are higher than those features of the call of *G. chrysosticta* (Table 1).

The description of the advertisement call of Baritú's Marsupial Frog has direct implications in the conservation efforts aimed at this species, because this information will be useful to set the parameters for the automated recognition software to detect frogs' vocalizations in monitoring/search programs that use passive acoustic monitoring with automated recording units.

The knowledge of the advertisement calls and vocal repertoires of the southern species of the *Gastrotheca marsu-*

piata species group is fragmentary. Particularly for the species from Argentina, the biggest concern is that the call descriptions of *G. christiani* and *G. gracilis* were based on a limited number of individuals and these calls were not referred to any voucher specimens (Vaira *et al.* 2011; Akmentins *et al.* 2014). Thus, the taxonomic value of call features of these descriptions is weak. Our results suggest that the advertisement call could be a reliable character for the reconnaissance of marsupial frog species from Argentina. Consequently, it would be desirable to count with a broader sample of vocalizations of the three species encompassed by the respective voucher specimens to solve the problems in the taxonomic identity of dubious populations (Laurent *et al.* 1986).

TABLE 1. Comparison of temporal and spectral features of the advertisement call of *Gastrotheca chrysosticta* with the advertisement call descriptions of *G. christiani*, *G. gracilis* and *G. piperata* available in the literature. Values are presented as the mean \pm standard deviation (minimum–maximum).

	<i>G. chrysosticta</i>	<i>G. christiani</i>	<i>G. gracilis</i>	<i>G. piperata</i>	<i>G. piperata</i>	<i>G. piperata</i>
Air temperature (°C)	8–11	11.5–18	7.7	12	16.6	21
Call duration (ms)	782.9 \pm 124.5 (609–1078)	1299 \pm 77 (1213–1402)	923 \pm 55 (853–1001)	1103 (1004.9–1567.1)	744.8 \pm 76.8 (657–965)	1435 \pm 63
Inter-call (ms)	2038.7 \pm 657 (1211–3645)	1748 \pm 282 (1506–2058)	2974 \pm 670 (2082–4341)	–	–	1616 \pm 99
Pulses per call	20.2 \pm 3.6 (15–29)	50 \pm 2.8 (47–54)	22 \pm 1.5 (20–24)	–	33 \pm 4.4 (28–41)	77 \pm 3.6
Pulse rate (pulses/s)	25.7 \pm 1.8 (23.1–28.6)	38 \pm 0.1 (38.5–38.8)	23.5 \pm 0.4 (23–24)	–	42.1 \pm 1.6 (40.8–44.7)	54 \pm 0.5
Dominant frequency (Hz)	1885.4 \pm 138.5 (1550.4–2250)	1910 \pm 71 (1800–2058)	1725 \pm 47 (1621–1814)	1913.6 (1837.5–2019.2)	1995.9 \pm 97.5 (1883–2125)	2100 \pm 30
Number of individuals/ number of calls analyzed	4/40	2/8	1/15	?/13	2/23	?/38
Reference	Present work	Vaira <i>et al.</i> 2011	Akmentins <i>et al.</i> 2014	De la Riva <i>et al.</i> 1995	Duellman & Köhler 2005	Sinsch & Juraske 2006

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