

# Vocal repertoire of an endangered marsupial frog of Argentina, *Gastrotheca christiani* (Anura: Hemiphractidae)

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**Abstract.** We quantitatively describe the vocal repertoire (advertisement and aggressive calls) of the endangered marsupial frog, *Gastrotheca christiani* from NW Argentina, comparing the spectral and temporal characteristics of vocalizations with other members of *G. marsupiata* species group.

**Keywords.** Advertisement calls, aggressive calls, *Gastrotheca marsupiata* species group, Argentina, Yungas.

## Introduction

The Neotropical genus of marsupial frogs *Gastrotheca* Fitzinger, 1843 comprises 58 species distributed from lowlands to above treeline, ranging from Costa Rica and Panama to northern Argentina, including eastern and southeastern Brazil (Frost, 2010). The *G. marsupiata* species group comprises small to moderate sized species present in the Andean slopes, including the species with southernmost distributional range of the genus (Duellman, Maxson and Jesiolowski, 1988). Scant morphological differences among species makes their identification difficult, hence advertisement calls are highly valuable in species recognition (Sinsch and Juraske, 2006).

In Argentina, the *G. marsupiata* species group comprises three endemic species, *Gastrotheca christiani* Laurent, 1967; *Gastrotheca gracilis* Laurent, 1969 and *Gastrotheca chrysosticta* Laurent, 1976, inhabiting the NW montane forests of Salta, Jujuy, Tucumán, and Catamarca provinces (Lavilla et al., 2000). They were described as highly cryptic habitat specialist species associated with rock crevices and tree hollows (Laurent, Lavilla and Terán, 1986). Previous studies showed that morphometric characters, coloration patterns, and distribution range could be of little help to distinguish this group of species (Laurent, Lavilla and Terán, 1986).

Also, usefulness of behavioral characters, even the most reliable, such as reproductive mode characteristics (presence or absence of free-living larvae) was particularly focused on by these authors because of the lack of data in several populations. In the absence of consistent characters to distinguish species, bioacoustics has proved to be a useful tool for the diagnosis of several anuran species (Angulo and Reichle, 2008; Goicoechea, De la Riva and Padial, 2010).

Although systematic relationships and aspects of ecology and reproductive behaviour of the species of *Gastrotheca* from Argentina have been formerly investigated (Barrio, 1976; Laurent, 1967; Laurent, 1969; Laurent, 1976; Laurent, Lavilla and Terán, 1986), no studies concerning the quantitative analysis of vocalizations of this species have been conducted since its original description (but see a spectrogram of *G. gracilis* call included in Laurent, 1976). There is an increasing concern of the current conservation status of Argentinean species of genus *Gastrotheca*, particularly by the endangered species *G. christiani* (IUCN, 2010), the only Argentinean species with complete development in the female's dorsal pouch (Laurent, Lavilla and Terán, 1986), which has no new records of individuals in their historic localities since the reported eradication of a reproductive aggregation in a protected area in 1996 (Vaira, 2003). Because advertisement calls are a conspicuous and reliable cue to detect species with such cryptic habits, the description of vocal repertoire of this species could be a useful tool for future inventories and monitoring programs.

The aim of the present work is to report and quantitatively describe the vocal repertoire of the endangered marsupial frog, *Gastrotheca christiani*, endemic from NW Argentina montane forests (Ecoregion of Southern Andean Yungas) comparing the

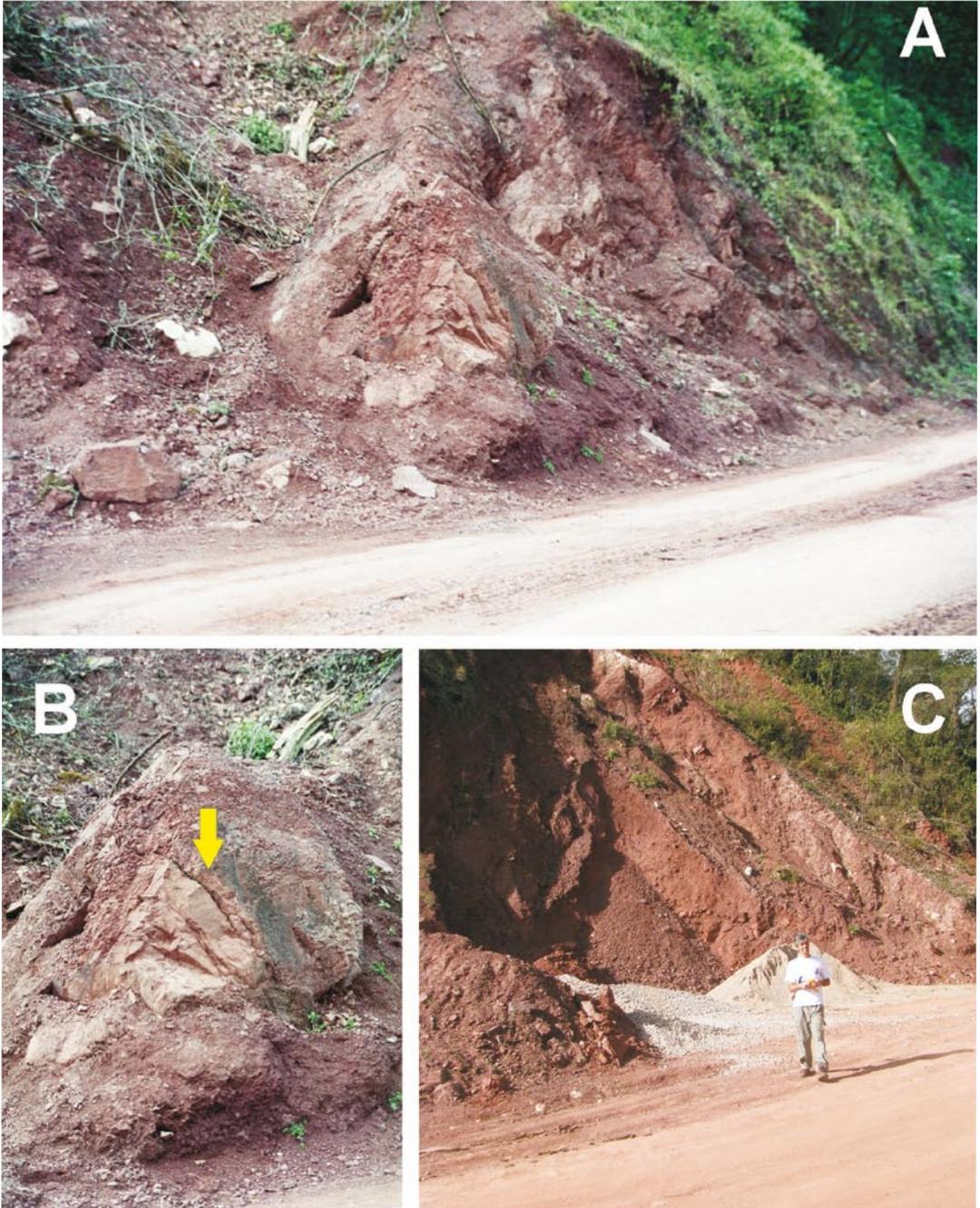
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**Figure 1.** (A) Breeding site of *Gastrotheca christiani* in Abra Colorada, Jujuy province, Argentina. (B) Detail of the isolated clay rock where males were recorded. The yellow arrow pointed out the crevice where males call. (C) Current aspect of the breeding site after the habitat alteration by road maintenance. Photos by M. Vaira and M. S. Akmentins.

spectral and temporal characteristics of vocalizations with others members of *G. marsupiata* species group.

### Materials and Methods

Vocalizations were recorded by MV on August 14 and Septem-

ber 2, 1995 at dusk in the type locality of *Gastrotheca christiani* at Abra Colorada, Valle Grande department, Jujuy province, (23°40'32" S; 64°53'55" W), an area of subtropical montane forest in northwestern Argentina at 1700 m of altitude. A Sony TCM-20DV tape recorder and a Sennheiser ME-66 microphone were used for records of the acoustic signal. Air temperature du-

**Table 1.** Comparison of temporal and spectral parameters of the advertisement call of six species of the *Gastrotheca marsupiata* species group. Mean  $\pm$  SD are indicated.

Call feature	<i>G. christiani</i>	<i>G. marsupiata</i>	<i>G. griswoldi</i>	<i>G. piperata</i>	<i>G. pseustes</i>	<i>G. peruana</i>
Call duration [ms]	1299 $\pm$ 77	450 $\pm$ 8	1332 $\pm$ 48	1435 $\pm$ 63	575 $\pm$ 18	628 $\pm$ 46
Intercall interval [ms]	1748 $\pm$ 282	820 $\pm$ 41	429 $\pm$ 17	1616 $\pm$ 99	493 $\pm$ 45	368 $\pm$ 47
Pulses per call [n]	50 $\pm$ 2.8	30 $\pm$ 0.4	72 $\pm$ 1.5	77 $\pm$ 3.6	45 $\pm$ 0.6	62 $\pm$ 1.9
Pulse rate [Hz]	38 $\pm$ 0.1	67 $\pm$ 0.7	59 $\pm$ 0.7	54 $\pm$ 0.5	83 $\pm$ 0.6	82 $\pm$ 1.6
Dominant frequency [Hz]	1910 $\pm$ 71	1940 $\pm$ 30	1980 $\pm$ 30	2100 $\pm$ 30	1550 $\pm$ 10	1870 $\pm$ 20

ring recordings was 18°C and 11.5°C respectively (August 14 and September 2). Male aggregations were calling inside deep crevices of an isolated clay rock (2.20 m of diameter at the base; 1.70 m of height) surrounded by exposed red clayey soil by the steep side of an unpaved road (Fig 1). Males never left such hiding place to vocalize where females and juveniles were also present (Vaira, 2003). We were unable to obtain call voucher specimens at the time of recordings since the collection implied the complete habitat destruction with undesired consequences on this endangered species. On 11 September 1996, this breeding aggregation experienced a complete habitat loss as a result of road maintenance activities (Fig 1). Thirteen frogs were found dead inside pieces of the rock and were collected as voucher specimens and deposited at the herpetological collection of the Museo de Ciencias Naturales, Universidad Nacional de Salta, Argentina (MCN 437). We determined the species as *G. christiani* thanks to a previously collected brooding female (MCN 349; see Fig. 2) from the same site maintained in captivity who gave birth to two froglets from the dorsal pouch (M. Vaira, personal observation).

Calls were digitized and analyzed with SoundRuler 0.9.6.1 software (available at <http://soundruler.sourceforge.net/>), which uses facultative algorithms for quick and objective acoustic measurement of sounds (Gridi-Papp, 2003). Sampling frequency was at a rate of 44100 Hz and with 16-bit resolution. Frequency information was obtained through Fast Fourier Transformation (width 256 points) at Hamm window function. The terminology used for the description of the calls follows Heyer et al. (1990). Quantitative parameters of advertisement and aggressive calls ( $n=4$  calls per male) were expressed as mean  $\pm$  one standard deviation. Call features were compared with published call descriptions of five taxa pertaining to the *Gastrotheca marsupiata* group: *G. griswoldi*, *G. peruana*, *G. piperata*, *G. pseustes*, and *G. marsupiata* (Sinsch and Juraske, 2006). These authors found dominant frequency and pulse per call to be temperature-independent call variables, and call duration was considered a temperature-dependent variable. However, temperature differences were found to be not significant in the range of 10 to 20°C (Sinsch and Joermann, 1989). Thus, comparison of the selected call features of *G. christiani* registered at 11.5°C and 18°C air temperature with the same call characteristics of the five members of the group referred by Sinsch and Juraske (2006) to an air temperature of 21°C were considered reliable.

## Results

Calling males were repeatedly heard from April to June and from August to November from dusk to midnight (1900 to 2400 h). As males never left hiding places to vocalize we were hindered from observing the existence of aggressive behavior as described in *G. marsupiata* (Sinsch and Joermann, 1989). We considered the vocal repertoire recorded in *G. christiani* composed of two different call types: advertisement calls and aggressive calls (Figs. 3 and 4). Similar calls reported to *G. marsupiata* support our assumption (Sinsch and Joermann, 1989). Advertisement calls consist of a trill, formed by 47 to 54 regularly repeated short pulses (mean 50.2 pulses  $\pm$  2.8 pulses) of 1213 to 1402 milliseconds of call duration (mean 1299.2 msec  $\pm$  77.7 msec), and intercall interval of 1506 to 2058 milliseconds (mean 1748 msec  $\pm$  282.2 msec). The dominant frequency peak was between 1800 and 2020.8 Hz (mean 1910.6 Hz  $\pm$  70.9 Hz). The pulse repetition rate ranged from 38.5 to 38.8 pulses per second (mean 38.6 pulses/sec  $\pm$  0.1 pulses/sec). Pulse duration and intervals between pulses were very regular (mean pulse duration 10.9 msec  $\pm$  1.1; and interpulse mean 15.7 msec  $\pm$  1.1). Spectral characters of the call showed frequencies with energy around the 1900 Hz where fundamental frequency equals dominant frequency. The call showed frequency modulation when it starts (Fig. 3). Detailed spectral data are summarized in Table 1.

The advertisement call of *G. christiani* was markedly longer than the call of *G. marsupiata* (450 msec), *G. pseustes* (575 msec), and *G. peruana* (628 msec); and similar to the call of *G. griswoldi* (1332 msec), and *G. piperata* (1435 msec). It consisted of fewer pulses per call than the call of *G. griswoldi* (72 notes), *G. piperata* (77 notes), and *G. peruana* (62 notes); but relatively similar than *G. pseustes* (45 notes), and higher than *G. marsupiata* (30 notes). The dominant frequency was higher than in *G. pseustes* (1550 Hz), but similar to



**Figure 2.** Brooding female of *Gastrotheca christiani* (MCN 349) collected in the breeding aggregation site in Abra Colorado, Jujuy province, Argentina. Photo by M. Vaira.

*G. marsupiata* (1940 Hz), *G. griswoldi* (1980 Hz), *G. piperata* (2100 Hz), and *G. peruana* (1870 Hz).

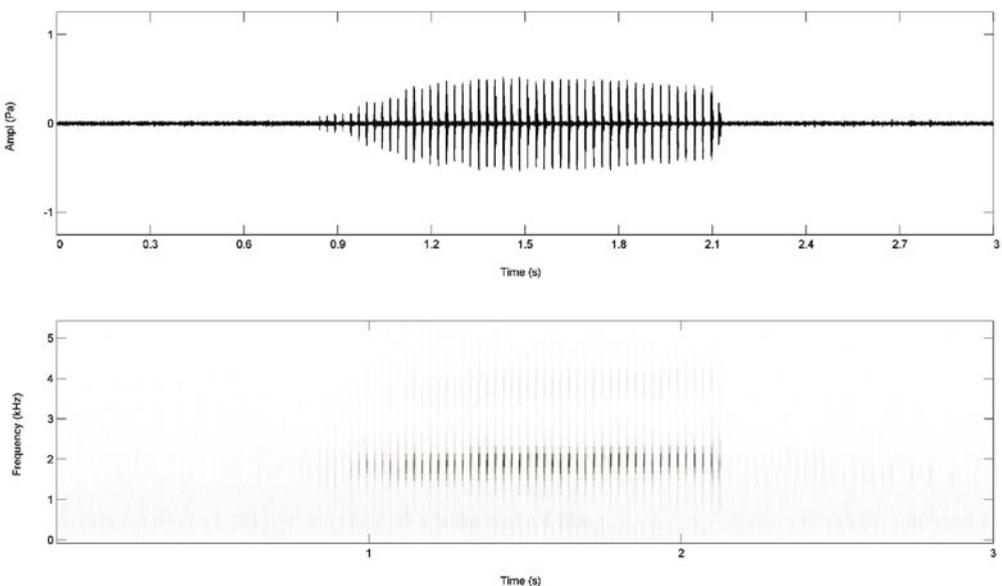
Aggressive calls consisted of two portions divided by intervals of 273 to 383 ms (Fig. 4). The first segment was a long call (1300 – 1640 ms) consisted of a long note with 35 to 50 pulses, resembling the advertisement call in the spectral and temporal parameters. However, it was slightly lower when the fundamental frequency equals the dominant frequency (1740 Hz). The second segment consists of 1 to 2 short notes (18 – 27 ms), with long intervals between them. Spectrally, it differed both

from the first segment and the long-range call by the fundamental (1400 Hz) and dominant frequency (2035 Hz).

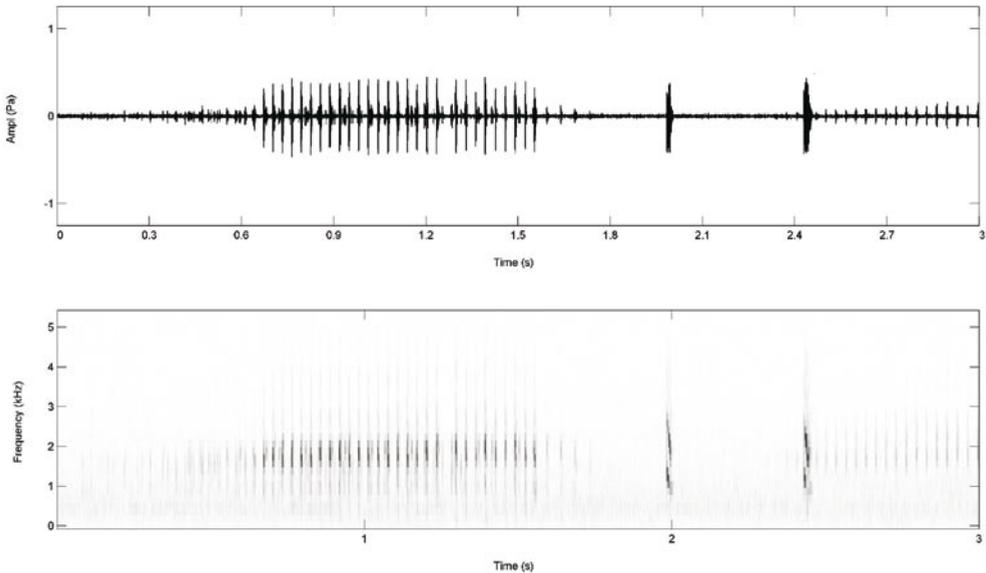
## Discussion

The advertisement call of *G. christinani* has very distinctive temporal and spectral characteristics of the five related species of *G. marsupiata* species group described by Sinsch and Juraske (2006). Unfortunately, complete descriptions of advertisement call of the other two Argentinean cryptic species, *G. gracilis* and *G. chrysostica*, are not available to test the effectiveness of advertisement call features as a tool for species diagnosis.

Sinsch and Joermann (1989) described the vocal repertoire in *G. marsupiata* and, considering the social context where these calls was emitted; they classified the single long-range note trill calls without additional notes as an advertisement call, and long-range note followed by short-range notes as aggressive calls. Aggressive calls are emitted by “resident” and “intruder” males approaching each other during interactions. This kind of vocal repertoire seems to be also recorded in *G. christinani*. De la Riva *et al.* (1995) described similar vocal repertoire for *G. piperata* (incorrectly assigned as *G. marsupiata*, *sensu* Duellman and Köhler 2005), but they consider that both calls could be different forms of advertisement calls. We registered that advertisement calls/aggressive calls ratio is approximately 10:1; for



**Figure 3.** Oscillogram and spectrogram of an advertisement call of *Gastrotheca christiani*, recorded 02 September 1995, Abra Colorado, Jujuy province, Argentina; air temperature 11.5°C.



**Figure 4.** Oscillogram and spectrogram of the territorial call of *Gastrotheca christiani*, recorded 14 August 1995, Abra Colorada, Jujuy province, Argentina; air temperature 18°C.

this reason, and in agreement with Sinsch and Joermann (1989), we considered that there were two distinct types of calls with different purposes and not a complex advertisement call emitted during vocal competitions, as occurs in *Physalaemus pustulosus* (Rand and Ryan, 1981).

Laurent (1976) observed and recorded the vocalizations of males of *G. gracilis* in captivity, the spectrograms of two types of vocalizations were referred by the author as “complete calls” (a multi-note vocalization followed by three additional notes) and “incomplete calls” (a multi-note trilled call). In spite of the lack of numerical data of temporal and spectral parameters of registered vocalizations of *G. gracilis*, this species seems to present the same vocal repertoire described in *G. marsupiata* and *G. christiani* with an advertisement call (incomplete calls *sensu* Laurent, 1976) and the aggressive call (complete calls *sensu* Laurent, 1976). Aggressive calls are a common feature on families of Neotropical terrestrial breeding anurans with prolonged breeding season such as Aromobatidae (Juncá, 1998), Dendrobatidae (Forti, Strüssmann and Mott, 2010), Leptodactylidae (Menin, Almeida and Kokubum, 2009), Eleutherodactylidae (Stewart and Rand, 1992), Strabomantidae (Wells, 1981), and Craugastoridae (Höbel, 2005). These aggressive vocalizations play a fundamental role in inter-male spacing and the maintenance of calling males’ territories (Wells, 2007).

More information on the reproductive biology and behavior of *G. christiani* may help to determine the

function of such a complex vocal repertoire in a habitat specialist frog who vocalizes in aggregations from inside rock crevices.

**Acknowledgments.** We would like to thank I. Martinez for useful suggestions on this manuscript. Field research was supported by a grant from CONICET to M. V. and a Seed Grant from DAPTF (E.O. Lavilla, Principal Investigator). Permits for field work were provided by Delegación Técnica de Parques Nacionales Regional Noroeste, Argentina. M. Vences made helpful comments on the manuscript.

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